BioMed Research International

Monitoring and Promoting Physical Activity and Physical Fitness in All Age Groups

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Guest Editors: and

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https://doi.org/10.1155/2024/9835396

Editorial

Monitoring and Promoting Physical Activity and Physical Fitness in All Age Groups

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Received 25 March 2023; Accepted 25 March 2023; Published 3 April 2024

1. Introduction

Modern lifestyle brings with it many different challenges, no less than in the past, but modern challenges are significantly different. Therefore, it is very important to understand most of the challenges that modern man faces. Among other things, one of the most important challenges is the preservation of health. Health was one of the most important resources in the past, and it is just as important today. However, the factors influencing the impairment of good health have changed over time. In order for human being to maintain good health, it had to define the determinants of health and carefully monitor changes in their impact on health status over time. The modern lifestyle has changed dramatically [1, 2], and physical activity and physical fitness have become one of the very important determinants of the modern men's health [3]. In the past, these determinants were not the focus of scientists' attention because physical activity and physical fitness were taken for granted. However, the lifestyle in the last few decades has led to the physical inactivity of modern man [4, 5], which was recognized by scientists who established in their research that physical activity and physical fitness are associated with health benefits for individuals of all ages. Thus, it is now widely known that achieving a sufficient level of physical activity and physical fitness additionally contribute to better health-related biomarkers [6]. Therefore, if time is spent in sedentary behavior, it is realistic to expect negative health outcomes. Understanding and developing strategies to promote physical activity behavior is much more important than in the past, as it is essential to improve physical fitness levels [7]. Although, at the beginning, special attention was focused on children, later these strategies were also focused on other generations, primarily young people, adults, and also the elderly. There is a large number of studies that increasingly confirm that negative outcomes are visible in individuals of all ages [8–10]. Facing modern challenges and the desire to improve the health status of all age groups, this research topic was created, with the intention of helping the upbringing of monitoring and promoting physical activity and physical fitness in all age groups.

2. Contribution to the Field

The purpose of this research topic was to gather the latest knowledge in the field of monitoring and promoting physical activity and physical fitness in all age groups. The eight studies that emerged as the output of this special issue have advanced the field in several ways.

First, some very interesting findings were reached in this research topic related to the monitoring of trends in morphological characteristics among children. The authors of this study have examined the current state, dynamics, and direction of changes in morphological characteristics, over a 30-year period in Serbian children and adolescents among 7- and 11-year-old, and observed significant increase in height, body mass, and BMI in 7-year-old children from 1990 to 2020 [11]. On the other hand, Han et al. [12] have confirmed the effectiveness of a family-based intervention that integrated the family and preschool based on a smartphone app they created to improve the moderate-to-vigorous physical activity and physical fitness of preschool children during COVID-19.

Another important stream of work is reflected in the studies that analyzed: (1) traditional Chinese exercise (qigong) for chronic obstructive pulmonary disease [13] and (2) exercise rehabilitation among cancer patients [14]. These studies help us understand the therapeutic properties of exercise. Specifically, the authors of the first mentioned study have conducted systematic review and meta-analyses and reached scientific evidences that can help for the management of chronic obstructive pulmonary disease, while the second group of authors has conducted a bibliometric and visualized knowledge graph analysis and reached the research hotspots and frontiers of exercise rehabilitation among cancer patients via CiteSpace.

One more important stream of work is reflected in three studies that analyzed the physical performance of sportsmen. Akpinar [15] had investigated the motor lateralization profiles of youth soccer players and compared the same lateralization to nonathletes and reached very interesting outcomes that participation in soccer training improves lower limb coordination and decreases motor lateralization. Furthermore, Türkmen and Biçer [16] have examined the effects of an 8-week orienteering training on physical fitness parameters in adolescents and confirmed that orienteering training once a week for eight weeks resulted in positive developments in physical fitness parameters. Zheng et al. [17] have followed the Cochrane Collaboration guidelines and assessed the effect of short- and long-term detraining on trained individuals' $\dot{V}$O2max through a systematic review and meta-analysis and reached interesting scientific evidences that are reflected in the fact that subjects with a higher $\dot{V}$O2max training status have a greater decline in oxygen uptake after long-term training cessation.

Lastly, de Souza et al. [18] have evaluated ultramarathons with distances above 180 km in relation to runners' peak ages and performances and reached interesting data. They monitored the period between 2010 and 2020 and observed the following: (1) increase in the number of ultramarathon running events; (2) Europe had the highest number; (3) women had low participation; and (4) performance progression fell.

3. Conclusion

This special issue of the journal Biomedical Research International entitled "Monitoring and Promoting Physical Activity and Physical Fitness in All Age Groups" was created, with the special intention of helping the upbringing of monitoring and promoting physical activity and physical fitness in all age groups. It is very difficult to conclude whether the goal of this research topic was achieved or not. The subject was set very broadly, and any advance is satisfactory. Namely, although expectations were higher, it is the fact this research topic justified its existence. Eight high-quality studies have been collected that have advanced the field of monitoring and promoting physical activity and physical fitness in all age groups. To this end, this research topic leveraged high-quality research studying changes in all generations, from children to elderly, to offer guidance to scientists in the first place, and also to practitioners and policy makers around the globe on how to monitor and promote physical activity and physical fitness as well as alleviate the consequences of physical inactivity.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Contributions

SP drafted the manuscript, and two other authors, BM and JJ, revised it. All authors approved the final version.

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Stevo Popovic
Juel Jarani

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Hindawi
BioMed Research International
Volume 2022, Article ID 4070658, 8 pages
https://doi.org/10.1155/2022/4070658

Research Article

Trends in Morphological Characteristics among 7- and 11-Year-Old Serbian Children: A Comparison between 1990 and 2020

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Received 28 June 2022; Accepted 17 September 2022; Published 29 September 2022

Academic Editor: Juel Jarani

Since knowledge possession about the morphological characteristics trend is important to understand, it is necessary to monitor the physical growth and children's development. We have aimed to examine the current state, dynamics, and direction of changes in morphological characteristics, over a 30-year period in Serbian children and adolescents. Morphological characteristics measured in 2020 ($n = 304$; age 7 ± 6 and 11 ± 6) were compared with the results of same-age children and adolescents from 1990 ($n = 1789$). The following characteristics were measured: body height, body mass, body mass index, forearm circumference, and upper arm skinfold. The average height (95% IP) of 7-year-old boys was significantly lower in all morphological variables in 1990, compared to their 2020 peers, while in forearm circumference was opposite. As for the 11-year-old boys, body mass ($p = 0.02$) and BMI ($p = 0.009$) had significantly better average values in 2020 than 1990, whereas forearm circumference (1.6-2.5 cm) and upper arm skinfold (2.7-4.9 cm) results were opposite. Seven-year-old girls from a 1990 sample also had significantly lower average values for morphological characteristics, compared to their 2020 peers. All morphological characteristic variables of 11-year-old girls have significantly better average values in 1990 sample than in 2020, except for body mass ($p = 0.47$) and BMI ($p = 0.55$). The current results have presented a true "picture" of the trends in morphological characteristics status among 7- and 11-year-old Serbian children by comparing them with the already obtained results 30 years ago.

1. Introduction

Insufficient physical activity has been identified as a global key risk factor for mortality [1]. Hypokinesia, as a reduction in the activity of the musculoskeletal system, increases susceptibility to many diseases, as well as general energy use [2], which further leads to increased concern for children's health, mainly because of their daily activities and habits. In addition, we are coming to a confusing situation where new technological innovations and discoveries are undoubtedly helping people to do different types of work faster and easier, but no attention is paid to energy consumption, which definitely decreases [3]. Furthermore, some authors [4, 5] believe that children usually spend most of their free time sedentary, in front of an electronic device (TV, phone, tablet, computer, etc.). Also, reduced activity is associated with many eating habits that can cause energy imbalance and obesity, both in children and adolescents [2]. Although Ostojić et al. [6] believe that it is not unhealthy to be obese as long as a person is in good physical shape, they set the important question "Does obesity cause more damage to the human body than physical inactivity?". Childhood obesity is expected to have more serious consequences for public health, given that being overweight in childhood usually continues into adulthood. Very poor fitness test results are also a crucial risk factor of diseases (diabetes, cancer, high blood pressure, osteoporosis, depression, anxiety etc.). Most of today's chronic diseases can be avoided only if quality upbringing and knowledge are passed onto children in early childhood, so that later, it can be implied with positive effect on adolescence and adulthood [2]. Given the worrying increase in hypokinesia in childhood, fundamental efforts should be made, in order to prevent long-term consequences [7]. Most public health recommendations actually encourage children and adolescents to exercise for at least 60 minutes of moderate to vigorous physical activity each day [1], so it is necessary to set another serious question, and it concerns which is whether children and adolescents meet the predefined criteria or not.

From birth to adulthood, a person's physical ability as well as physical development is influenced by many factors, both internal and external. We learn about the stages of development by monitoring the physical development and individual growth. Also, measuring and monitoring the children and adolescents growth are measured with the help of anthropometry [8]. It is necessary to monitor the physical growth and development of children, especially in the younger school age, because their body is subject to many external influences whose effects are felt only in the later period, which are very difficult to repair in later life [9]. Physical growth and development are first defined by body height and mass, while the crucial importance is the fact that in certain stages of ontogenetic growth and development, the influence and interaction of genetic factors in children is not the same. We associate morphological characteristics with bio-psycho-social status. It represents a set of characteristics that make up the constitution, body composition, structure, or assembly as an organized and relatively constant totality of characteristics in relation to each other. Also, endogenous factors represent internal factors, such as genetic and hormonal factors, while exogenous factors represent external factors, such as diet and physical activity [10].

Several authors have concluded that children who develop in more affluent conditions tend to have longer legs [11–13] and longer arms [12, 13], in relation to total body height. However, the results of changes in height and mass vary among countries in all socioeconomic groups [14], and the same changes are similar for both boys and girls [1, 15]. The prevalence of obesity and body size values has increased in most developed countries [15, 16], but in recent years, according to some authors [17, 18], the same parameters are only maintained. The prevalence of obesity was dominant in Eastern European countries compared to the rest of the continent and the United States [15]. It is purposefully recommended precisely because of its positive impact on many health aspects, body composition, cardiorespiratory fitness, mental health, attitude towards life, and even general physical activity [19]. Thus, the number of obese children and children with overweight is constantly increasing [20], children are increasingly moving, and thus, there is a slower development of motor skills.

Knowledge possession about the trends of morphological characteristics of children and adolescents is important to understand, given that they are related to many health outcomes. Also, the results may indicate a possible suppression of the negative trend [21], and in relation to the fact of high prevalence of increasing morphological characteristics, we can say that the current situation can be worrying [22]. Hence, we have aimed to examine the current state, dynamics, and direction of changes of secular trends in morphological characteristics, on a sample of 7- and 11-year-old Serbian children and adolescents, based on the first measurement that has been conducted 30 years ago.

2. Materials and Methods

2.1. Sample of Participants. The total participant sample was defined by the first measurement ($n = 1789$), conducted by Ahmetović et al. [23] in 1990. In order to ensure result comparability in 2020, the sample ($n = 304$) with same age (7 ± 6 months and 11 ± 6 months) was taken into consideration. Furthermore, the participants were taken from primary schools from Valjevo and Mionica. The number of participants in both time points is presented in Table 1.

2.2. Measurements. In order to examine the physical development, morphological variables were used at the first measurement: body height, body mass, body mass index (BMI), forearm circumference, and upper arm skinfold.

All measurement were conducted by the trained measurers, i.e., physical education teachers, as well as with the International Biological Program (IBP) recommendations [24]. In order to measure the defined variables, the following equipment was used in the measurement procedure: anthropometer by Martin, medical decimal weight, measuring tape (1 m long), and caliper.

If the time determinant is observed, this research is longitudinal and follows the time of 30 years (1990-2020), with the first research being conducted by the Ahmetović et al. [23]. The research was conducted in the school gymnasiums of the elementary school “Milan Rakić” from Mionica, primary school in Valjevo, and the fitness center “Top Form” Valjevo.

2.3. Statistical Analysis. Data will be presented as arithmetic mean (AS with 95% confidence interval (95% IP)) and standard deviation (SD). A participant sample from 1990 and 30 years later in the variables of morphological characteristics was compared with independent t-test tested whether statistically significant average difference (95% IP, standardized difference error (SE)) between the arithmetic means of the groups. Welch's test for unequal variance between groups was used as well. Differences between the years of sampling of morphological characteristics were assessed by individual t-test in children in relation to age and sex (7-year-old boys and girls, as well as 11-year-old boys and girls).

The level of inference was previously set at the level of $p \leq 0.05$. Statistical analysis and graphical display were done using GraphPad [25] and Microsoft Excel [26].

3. Results

3.1. Morphological Characteristics of 7- and 11-Year-Old Boys (1990-2020). In the 1990 sample, 7-year-old boys' height (95% IP) was between 127.2 and 128.3 cm, and body mass was from 26.82 to 27.74 kg, with BMI value of $16.91 \pm 3.63\,kg/m^2$. Their forearm circumference was between 17.58 and 17.88 cm, along with upper arm skinfold from 8.2 to 8.9 cm.

Table 1: The number of participants in both time points.

Year	Participant sample	
1990	$n_7 = 858$ (M = 430; F=428) $n_{11} = 931$ (M = 455; F = 476)	$\sum = 1789$
2020	$n_7 = 143$ (M = 79; F = 64) $n_{11} = 161$ (M = 94; F = 67)	$\sum = 304$

Legend: n_7: 7-year-old participants; n_{11}: 11-year-old participants; M: male; F: female; $\sum$: total number of participants.

Furthermore, 11-year-old boys' height (95% IP) was between 146.9 and 148.2 cm, and body mass was from 39.5 to 41.2 kg, with BMI value of 18.67 ± 4.11 kg/m^2. Their forearm circumference was between 20.1 and 20.4 cm, along with upper arm skinfold from 10.3 to 11.3 cm. In the 2020 sample, 7-year-old boys' height (95% IP) was between 130.53 and 132.92 cm, while body mass ranged from 29.93 to 33.86 kg, with BMI value of 18.58 ± 3.57 kg/m^2. Their forearm circumference was between 18.85 and 18.02 cm, along with upper arm skinfold from 13.78 to 16.00 cm. Furthermore, 11-year-old boys' height (95% IP) was between 146.2 and 149.2 cm, and body mass ranged from 41 to 45.2 kg, with BMI values 19.93 ± 4.71 kg/m^2. Their forearm circumference was between 21.81 and 22.71 cm, along with upper arm skinfold from 13.63 to 15.52 cm.

In 1990, the average height (95% IP) of the 7-year-old boys was significantly lower in all morphological variables, compared to their 2020 peers, body height 2.6-5.3 cm and body mass 2.6-6.6 kg, as well as in BMI ($p < 0.0001$) and upper arm skinfold 5.2-7.5 cm, while in forearm circumference (1.1-10.3 cm) was opposite. As for the 11-year-old boys, body mass ($p = 0.02$) and BMI (0.009) had significantly better average values in 2020 than 1990, while in terms of forearm circumference (1.6-2.5 cm) and upper arm skinfold (2.7-4.9 cm), it was opposite. Differences in morphological characteristics between 7- and 11-year-old boys measured in 1990 and 2020 are presented in Table 2.

3.2. Morphological Characteristics of 7- and 11-Year-Old Girls (1990-2020). In 1990, the average height (95% IP) of 7-year-old girls was between 126.5 and 127.8 cm, and body mass was from 26.17 to 17.19 kg, with BMI value of 16.55 ± 3.48 kg/m^2. Their forearm circumference was between 17.36 and 17.66 cm, along with upper arm skinfold from 9.08 to 9.92 cm. Furthermore, the average height (95% IP) of 11-year-old girls was between 148.9 and 150.4 cm, and body mass was from 39.9 to 41.6 kg, with BMI value of 18.36 ± 4.38 kg/m^2. Their forearm circumference was between 19.7 and 20.1 cm, along with upper arm skinfold from 10.9 to 11.8 cm. In 2020, 7-year-old girls' height (95% IP) was between 128.4 and 131.2 cm, and body mass varied from 27.73 to 31.73 kg, with BMI value of 17.86 ± 3.68 kg/m^2. Their forearm circumference was between 19.56 and 36.78 cm, along with upper arm skinfold from 13.24 to 16.38 cm. Furthermore, 11-year-old girls' height (95% IP) was between 144.8 and 148.5 cm, and body mass was from 37.44 to 42.25 kg, with BMI value of 18.69 ± 4.78 kg/m^2.

Table 2: Morphological characteristics in 7- and 11-year-old boys measured 1990 and 2020.

Variables	Age	Mean ± SD 1990	Mean ± SD 2020	p
BH (cm)	7	127.78 ± 5.94	131.73 ± 5.37	<0.001
	11	147.55 ± 7.53	147.67 ± 7.45	0.888
BM (kg)	7	27.28 ± 4.86	31.89 ± 8.76	<0.001
	11	40.35 ± 9.23	43.06 ± 10.30	0.020
BMI (kg/m^2)	7	16.91 ± 3.63	18.58 ± 3.57	<0.001
	11	18.67 ± 4.11	19.93 ± 4.71	0.0096
FC (cm)	7	17.73 ± 1.53	23.43 ± 20.48	0.016
	11	20.23 ± 1.97	22.27 ± 2.13	<0.001
UAS (cm)	7	8.54 ± 3.57	14.89 ± 4.95	<0.001
	11	10.78 ± 5.40	14.58 ± 4.63	<0.001

Legend: BH: body height; BM: body mass; BMI: body mass index; FC: forearm circumference; UAS: upper arm skinfold; SD: standard deviation; p: p value.

Their forearm circumference was between 20.86 and 21.9 cm, along with upper arm skinfold from 11.56 to 16.74 cm.

Seven-year-old girls from a 1990 sample had significantly lower average values of morphological characteristics, compared to their 2020 peers: body height ($p = 0.001$), body mass (0.004), BMI ($p = 0.009$), forearm circumference (2-19.3 cm), and upper arm skinfold (3.7-7 cm). All morphological characteristic variables of 11-year-old girls have significantly better average values in 1990 than in 2020, except for body mass ($p = 0.47$) and BMI ($p = 0.55$). Body height in the 1990 sample was lower (1-5 cm), along with forearm circumference (1-2.1 cm) and upper arm skinfold (0.2-5.4 cm). Differences in morphological characteristics between 7- and 11-year-old girls measured in 1990 and 2020 are presented in Table 3.

3.3. Standardized Differences in Morphological Characteristics of 7- and 11-Year-Old Boys (1990-2020). The average difference in body height ($g = 0.7$ [0.45, 0.94]) and body mass ($g = 0.68$ [0.34, 0.92]) of 7-year-old boys (1990-2020) is between large and small and in favor of 7-year-old boys from the year of 2020. As far as the BMI is concerned, the difference was small to moderate ($g = -0.46$ [-0.69, -0.24]). Likewise, the average difference between 7-year-old boys from 1990 and 2020 ranges from small to moderate in favor of the 2020 sample in forearm circumference ($g = 0.52$ [0.27, 0.76]). Seven-year-old boys from year of 2020 have presented much bigger average level of upper arm skinfold ($g = 1.49$ [1.23, 1.75]).

In 11-year-old boys, the differences in body height were trivial ($g = 0.02$ [-0.21, 0.24]) while in terms of body mass and BMI were trivial to moderate, respectively ($g = 0.28$ [0, 0.5]; $g = -0.30$ [-0.52, -0.08]). In addition, it was noted moderate to large differences in forearm circumference ($g = 0.99$

Table 3: Morphological characteristics in 7- and 11-year-old girls measured 1990 and 2020.

Variables	Age	Mean ± SD 1990	Mean ± SD 2020	p
BH (cm)	7	127.15 ± 6.4	129.75 ± 5.62	<0.001
	11	149.63 ± 8.24	146.65 ± 7.56	0.004
BM (kg)	7	26.68 ± 5.36	29.73 ± 7.99	0.004
	11	40.76 ± 9.42	39.84 ± 9.86	0.474
BMI (kg/m^2)	7	16.54 ± 3.48	17.86 ± 3.68	<0.001
	11	18.36 ± 4.38	18.69 ± 4.78	0.55
FC (cm)	7	17.51 ± 1.53	28.17 ± 34.47	0.016
	11	19.85 ± 1.95	21.38 ± 2.12	<0.001
UAS (cm)	7	9.45 ± 3.94	14.81 ± 6.28	<0.001
	11	11.36 ± 4.85	14.15 ± 10.62	0.038

Legend: BH: body height; BM: body mass; BMI: body mass index; FC: forearm circumference; UAS: upper arm skinfold; SD: standard deviation; p: p value.

[0.75, 1.22]) as well as in upper arm skinfold ($g = 0.76$ [0.53, 0.98]). Hedge's g with 95% confidence interval for morphological differences between 7- and 11-year-old boys (1990-2020) are presented in Figure 1.

3.4. Standardized Differences in Morphological Characteristics of 7- and 11-Year-Old Girls (1990-2020). The average differences in body height ($g = -0.38$ [-1.63, -0.12]) and BMI ($g = -0.37$ [-0.64, -0.11]) are trivial to moderate in a 1990 sample, respectively, while in the terms of body mass, the difference is only trivial ($g = -0.09$ [-0.35, 0.16]). Likewise, the average forearm circumference of 7-year-old girls is moderate than the 2020 sample ($g = 0.75$ [0.49, 1.01]), while the upper arm skinfold results are moderate than the 2020 sample ($g = 0.36$ [0.1, 0.62]).

In 11-year-old girls, the differences in body height ($g = 0.47$ [0.29, 0.65]), body mass ($g = 0.5$ [0.32, 0.68]), and forearm circumference ($g = 0.53$ [0.35, 0.71]) are between small and moderate than in the 2020 sample compared to the 1990 sample, while in terms of upper arm circumference, the 2020 sample is showing much higher values, compared to the 1990 sample ($g = 1.08$ [0.89, 1.26]). As far as the BMI is concerned, the difference was trivial ($g = -0.07$ [-0.33, 0.18]). Hedge's g with 95% confidence interval for morphological differences between 7- and 11-year-old girls (1990-2020) are presented in Figure 2.

4. Discussion

The study aim was to examine the current state, dynamics, and direction of changes in morphological characteristics, on a sample of 7- and 11-year-old Serbian children and adolescents, based on the first measurement that has been conducted 30 years ago. The main study findings are that average height (95% IP) of 7-year-old boys was significantly lower in all morphological variables in 1990, compared to their 2020 peers, while in forearm circumference was opposite. As for the 11-year-old boys, body mass ($p = 0.02$) and BMI (0.009) had significantly better average values in 2020 than 1990, whereas forearm circumference (1.6-2.5 cm) and upper arm skinfold (2.7-4.9 cm) results were opposite. Seven-year-old girls from a 1990 sample also had significantly lower average values of morphological characteristics, compared to their 2020 peers. All morphological characteristic variables of 11-year-old girls have significantly better average values in 1990 than 2020, except for body mass ($p = 0.47$).

The independent sample t-test revealed that significance in terms of 7-year-old boys and girls is shorter, lighter, and less adipose. Although boys showed a better trend in morphological characteristics, our study results agrees with the Kasović et al. [27], who also showed that boys have lower values of subcutaneous tissue mass and fat mass compared to girls. It should be noted that it is already a well-known fact that girls are more adipose than boys [28, 29]. In addition, it is necessary to take into account proper nutrition, adequate physical activity, sedentary activities, and sleep quality, since the negative impact on these parameters increases the possibility of overall health risk [30]. The result diversity can be also explained by the sample heterogeneity, age categories, statistical data processing, and even different time periods for estimating the secular trend of morphological parameters [31].

Significantly higher values of forearm circumference and skinfold were observed in favor of children from 2020, while body height and body mass did not differ significantly. Identical to 7 year olds, 11 year olds show an increased trend in morphological characteristics, and the results correspond to several studies as well [32–34]. On the other hand, between 1971 and 2018, Kocić et al. [35] determined a moderate effect of size in body height, for boys ($d = 0.43$) and for girls ($d = 0.14$), and in body mass, for boys ($d = 0.5$) and for girls ($d = 0.62$). However, due to the additional time point of measurement (2014), the same authors came to a significant effect size in the case of both genders. Meanwhile, between 1971 and 2014, the effect of body height was $d = 1.28$ for 11-year-old boys while for 11-year-old girls was $d = 1.19$. The case of body mass was $d = 1.02$ for 11-year-old boys while for 11-year-old girls was $d = 1.04$. Also, between 2014 and 2018, the effect of body height of both sexes was also large (boys: $d = 0.85$; girls: $d = 1.19$), as in the case of body mass (boys: $d = 0.37$; girls: $d = 0.39$). Božić-Krstić et al. [36] have also found an increased trend in body mass in 11-year-old children between 1971 and 1991, where the increased trend actually declined during 2001, most likely due to the economic situation at that period of time. Therefore, it is necessary to reconsider physical activities in physical education classes [37], both in Serbia and in other countries, based on the noticeable morphological changes. The fact that possible changes in school ergonomics could occure should also not be excluded [38], as well as a greater emphasis on more frequent and serious health status evaluations.

The results showed that all variables of morphological characteristics of 11-year-old boys had significantly better

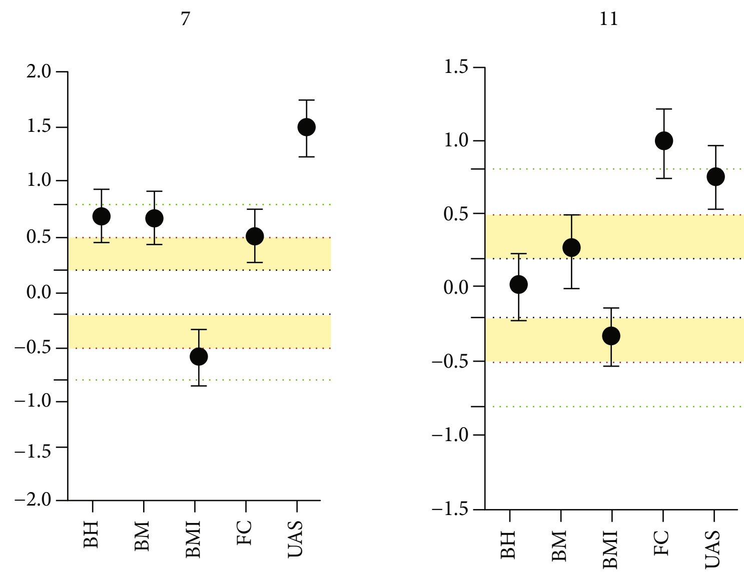

Figure 1: Standardized differences in morphological characteristics of 7- and 11-year-old boys. Legend: BH: body height; BM: body mass; BMI: body mass index; FC: forearm circumference; UAS: upper arm skinfold.

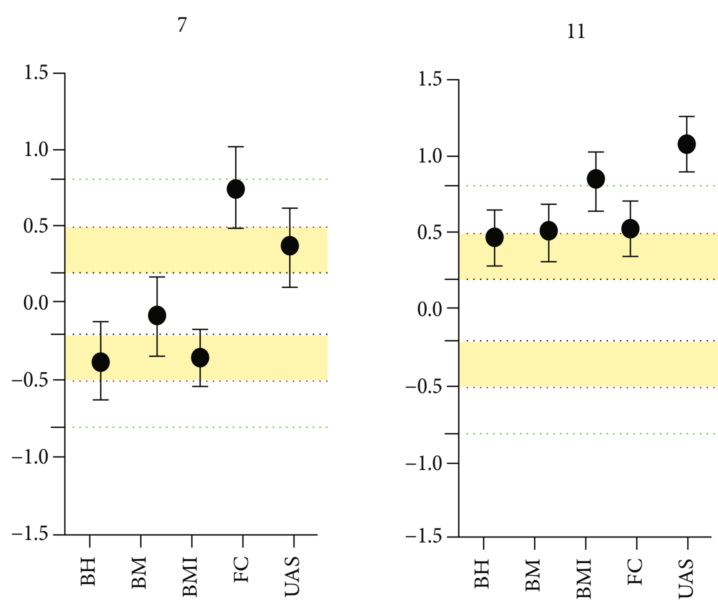

Figure 2: Standardized differences in morphological characteristics of 7- and 11-year-old girls. Legend: BH: body height; BM: body mass; BMI: body mass index; FC: forearm circumference; UAS: upper arm skinfold.

average values in 1990 than in 2020, except in the case of trivial differences in body height. In the case of 11-year-old girls in the 1990 sample, significant average values of all morphological characteristics were presented, except the body mass. Also, the results have showed increased body mass trend of children from 2020 (boys: $g = 0.28$; girls: $g = 0.5$). Since these differences are slightly more pronounced in boys than in girls, these results are consistent with Runhaar et al. [32]. In addition, based on the positive correlation and motor abilities with the maturity of boys and girls, we can say that maturity has an independent effect not only on physical fitness but also on the children's morphological structure [39]. Furthermore, there are fewer games that require any kind of movement, since today's children are spending more time at home sedentary, with some electronic devices (television, computer, or mobile phone) [40]. Therefore, if changes are not made in a certain period of time, difficulties can arise when the child completes the first grade [41], and when morphological difficulties occurs, there is a possibility that the negative trend will increase in the upper grades as well.

Based on the obtained results of the Hedge g test with 95% confidence interval for differences between morphological characteristics in relation to sex, children aged 7 years in

1990 and 2020, 7-year-old boys in 1990 show a positive trend in body height ($g = 0.7$), body mass ($g = 0.68$), upper arm skinfold ($g = 1.49$), and forearm circumference ($g = 0.52$). On the other hand, girls in 1990 were slightly taller ($g = -0.38$) and less adipose (forearm circumference: $g = 0.75$; upper arm skinfold: $g = 0.36$), with trivial differences in body mass ($g = -0.09$). Sedlak et al. [42] identified similar results on an identical sample over a period of 55 years. Namely, through 5 time point measurements, skinfolds (triceps, subscapular, and suprailiac) showed a significant positive trend in the case of both sexes, which partially agrees with our results. It should also be noted that the same study through two-time measurements (1957 and 1990) showed somewhat less significance; however, a more pronounced change in adiposity variables appeared during the last measurement (2012). Regarding body height and mass, development increased according to the time period of measurement [43], which also partially agrees with our results, since the body mass of girls changed trivially. If we take into account the time points of our study with Sedlak et al. [42], we should not ignore significant social and economic changes that have led to lifestyle changes, which further resulted in increased obesity prevalence [1].

Based on the obtained results of the Hedge g test with 95% confidence interval for differences between morphological characteristics in relation to sex, children aged 11 years in 1990 and 2020, boys have showed significantly better values of morphological characteristics, except in the case of body height ($g = 0.02$), while girls also showed significant average values of all morphological characteristics, except in the case of body mass ($g = 0.5$), in relation to the 2020 sample. The results presented in this way can be compared with the Costa et al. [33] results, who have presented significant differences over time in the variables of body mass but not in boys' body height. The same authors also identified significant changes in the body height and mass of girls, which partially agrees with our results. Differences in forearm circumference and upper arm skinfold agree with the results of Dollman and Stephen [44], and the same variables were more pronounced in girls than in boys. Variations in the results of morphological characteristics over time could be related to adequate diet and even eating habits, especially during the period when children are in school [45], which should be taken into consideration.

5. Conclusion

Reduced children's physical activity leads to a change in morphological characteristics. In addition, in certain stages of growth, the influence/interaction of genetic and environmental factors is not the same. The results of the current research have presented a true "picture" of the trends in morphological characteristics status among 7- and 11-year-old Serbian children by comparing them with the results from 30 years ago. From 1990 to 2020, we observed increase in height, body mass, and BMI in 7-year-old children. Although we have not included additional time points for morphological evaluation, as well as the fact that we have had included, only a few morphological variables could be considered as our main study limitations. Therefore, the conclusions regarding secular trends in morphological characteristics should include several time point measurements, along with more included morphological variables.

Data Availability

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Hindawi
BioMed Research International
Volume 2022, Article ID 1036775, 9 pages
https://doi.org/10.1155/2022/1036775

Research Article

Ultramarathon Evaluation above 180 km in relation to Peak Age and Performance

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Received 2 June 2022; Revised 13 July 2022; Accepted 27 July 2022; Published 26 August 2022

Academic Editor: Bojan Masanovic

Background. Ultramarathons with distances over 180 km might lead to different results regarding participation, performance, and age compared to shorter runs of 50 and 100 km. *Objective*. To evaluate ultramarathons with distances above 180 km in relation to runners' peak age and performance. *Methods*. Verification of the quantity of competitions in runs over 180 km by continents in the period 2000 to 2020 and evaluation of the individual results of 13,300 athletes after 2010. *Results*. Europe stood out with the largest number of organized events, followed by Asia and North America. The age peak performance (PP) in men and women averaged 45 years old with relationship between sex × years ($F = 3.612$, $p < 0.001$; $\eta^2 = 0.003$). Men accounted for more than 80% of the runners and showed a reduction in PP from 2015 onwards ($p < 0.001$). Competitions between 180 and 240 km were the most frequent, particularly after 2016, surpassing the number of marathons over 360 km ($p < 0.001$). Men and women showed higher velocity in distances ($p < 0.001$) from 180 to 240 km when compared to 241 to 300 km, 301 to 360 km, and >360 km courses. *Conclusions*. The decade between 2010 and 2020 showed an increase in the number of Ultramarathon running events. Europe had the highest number. Women had low participation. Performance progression fell, a fact associated with an increase in the number of participants and not specifically related to a decline in athletic performance over the years.

1. Introduction

In recent years, there have been a consolidation and increase in the number of Ultramarathon (UMs) events around the world [1]. Previous research has been carried out in order to understand the profile of runners (i.e., sex, age, and economic status), age peak, and performance progression (PP), especially in 50 km and 100 km runs [2]. In summary, these studies have shown that the runners are male, aged over 35 years, and have undergone systematic training [3].

Generally, ultramarathoners were the oldest, compared to marathon and half-marathon runners [4]. When analyzing the performance of 2,067 100 km runners around the world during the past 59 years, an increase in the number of participants over 60 years was identified [5]. For 100 km, runners between 45 and 49 were the most successful athletes [2]. In the 161 km marathon, the age between 40 and 44 were the years with the highest number of successful finishers. Furthermore, it has been found that athletes over 70 years of age have improved running velocity every decade [1].

Previous studies have indicated that age [4], anthropometric characteristics [6, 7], and training experience [8] were associated with successful ultramarathon performance, especially in distances up to 100 km in the first days of the UMS. However, currently, the participation in challenges over 180 km is advancing. These competitions are considered extreme events exceeding 1000 km, making them a superior challenge, which presents the athletes with a series of adversities (i.e., extreme weather conditions and nutritional care) [9]. Thus, an understanding of the profile of athletes is important to guide their training and preparation for long-term performance.

An analysis of an ultramarathon over 180 km might lead to different results regarding participation and performance for both elite and aged group runners compared to an event covering distances such as 50 and 100 km. Research on variations in sex differences by age group would be expected to provide insights into differences in biological mechanisms of aging (e.g., hormonal changes) between women and men runners [10]. Further, UMs are quite different than shorter distances; there is great interest in knowing peculiarities in capabilities owing to the low [9]. An analysis of this difference in velocity might affect performance level.

This analysis is essential in strategic sports planning as it directs and contributes to the planning of the evolutionary phases up to the peak of physical development and potentiates victory in professional-level sporting events [4]. Despite the relevance of the studies already existing, there is a lack of data about the participation and performances in the UMs longer than 100 km. Our hypothesis was that the runners were more experienced, had higher PP, and ran at a reduced speed, given the increased distance. The objective of the present study was to evaluate ultramarathons above 180 km in relation to peak age and performance of the participants.

2. Materials and Methods

The present study presents a retrospective cohort design. A total of 1,202 worldwide ultramarathon events taking place between 2000 and 2020 were analyzed, with distances ≥ 180 km. All data used were downloaded manually from the DUV website (Deutsche Ultramarathon Vereinigung; https://statistik.d-u-v.org/) during February/2021.

A first analysis of the frequency of races in the period 2000 to 2020 was carried out. Based on these data, a second analysis was carried out for the years 2010 to 2020 (identified as an expressive period of the quantity of organized races), on the individual results of 13,300 athletes (11,646 men and 1,654 women), in the top 20 ultramarathoners. For analyzing average velocity over these years, both top 10 and top 20 ultramarathoners were also analyzed. The variables analyzed were as follows: age, sex, speed, distance, performance, and nationality. The athlete's age was computed taking into account only the year of birth; then, this information was used to determine the age of peak performance, taking into account previous studies [4].

2.1. Statistical Analysis. Descriptive analyses were performed to present the main characteristics of the events (number of events, distance of competition, number of finalists, and continental predominance) and runners (year of birth and sex). Data characterization was expressed as mean and standard deviation for continuous quantitative variables, percentage, and frequencies for categorical variables. The tests were also analyzed in a stratified way by distances from 180 to 240 km, 241 to 300 km, 301 to 360 km, and above 360 km. Events described in miles were converted to kilometers for categorization. To verify the distribution of the sample, when necessary, normality was verified using the Kolmogorov-Smirnov test, considering the total sample. The t-test for independent samples was applied to analyze the area under the curve. The ANOVA test (Two-Way) was used for PP and velocity comparisons between sex × time periods (years) and for velocity stratified between sex × distance, followed by the Bonferroni post hoc test. Partial eta square (η^2) was calculated for each model and used as a measure of effect size considering small ≥ 0.01, medium ≥ 0.06, and large ≥ 0.14. The histogram of the age of male and female finalists was determined by 5-year age intervals. The relationship between velocity and distance was verified by Pearson's correlation. The magnitude of the correlation was determined as follows: $r < 0.1$, trivial; $r = 0.1–0.3$, small; $r = 0.3–0.5$, moderate; $r = 0.5–0.7$, strong; $r = 0.7–0.9$, very strong; $r = 0.9–0.99$, almost perfect; and $r = 1.0$, perfect. Statistical Package for Social Sciences (SPSS) version 20® and GraphPad Prism version 7.00, respectively, were used for all statistical and graphical analyses, adopting a significance level of $p < 0.05$.

3. Results

3.1. Continents and Countries' Ultramarathon Events. Europe stood out with the largest number of organized events, followed by Asia and North America, totaling more than 92% of the UMs held in the world. The other continents had few (Figure 1). Japanese, American, British, French and Korean nationalities were the most common among UM runners (Figure 2(a)). The country with the

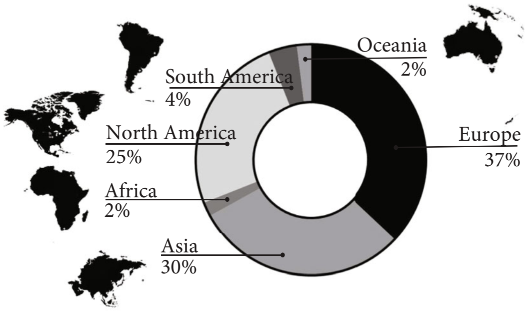


Figure 1: Distribution of ultramarathon events by continent.

highest absolute frequency (n_i) of ultramarathon events was the Unites States ($n_i = 329$), followed by Japan ($n_i = 231$), Great Britain ($n_i = 112$), Korea ($n_i = 91$), and Greece ($n_i = 70$) (Figure 2(b)).

Figure 3(a) shows an increase in the number of competitions from the year 2010, reaching a peak in the year 2019 with approximately 200 events. In 2020, the number of events was reduced to fewer than 100 events. There was an increase in the area under the curve in the decades from 2010 to 2020 when compared to the years 2000 to 2010 (1083 ± 517 vs. 306 ± 93 ; $p < 0.001$) (Figure 3(b)). The number of women finalists in UMs in distances over 180 km represented a small percentage compared to men. An increase of 4% in female participation was observed in relation to the total number of participants, when comparing the years 2010 (12%) and 2020 (16%) (Figure 3(c)). Marathons with courses from 180 to 240 km were the most usual in all years. The frequency of UMs performed with distances above 360 km showed an increasing trend from the year 2016 when compared to distances from 301 to 360 km and in 2019 when compared to distances from 241 to 300 km (Figure 3(d)).

3.2. Sex Participation. When the absolute frequency of participation among men was verified, there was an increase of 405% between 2011 ($n_i = 452$) and 2019 ($n_i = 1825$), the years with the lowest and highest frequency of runners, while female participation increased 467% between 2010 (64) and 2019 (305) (Table 1).

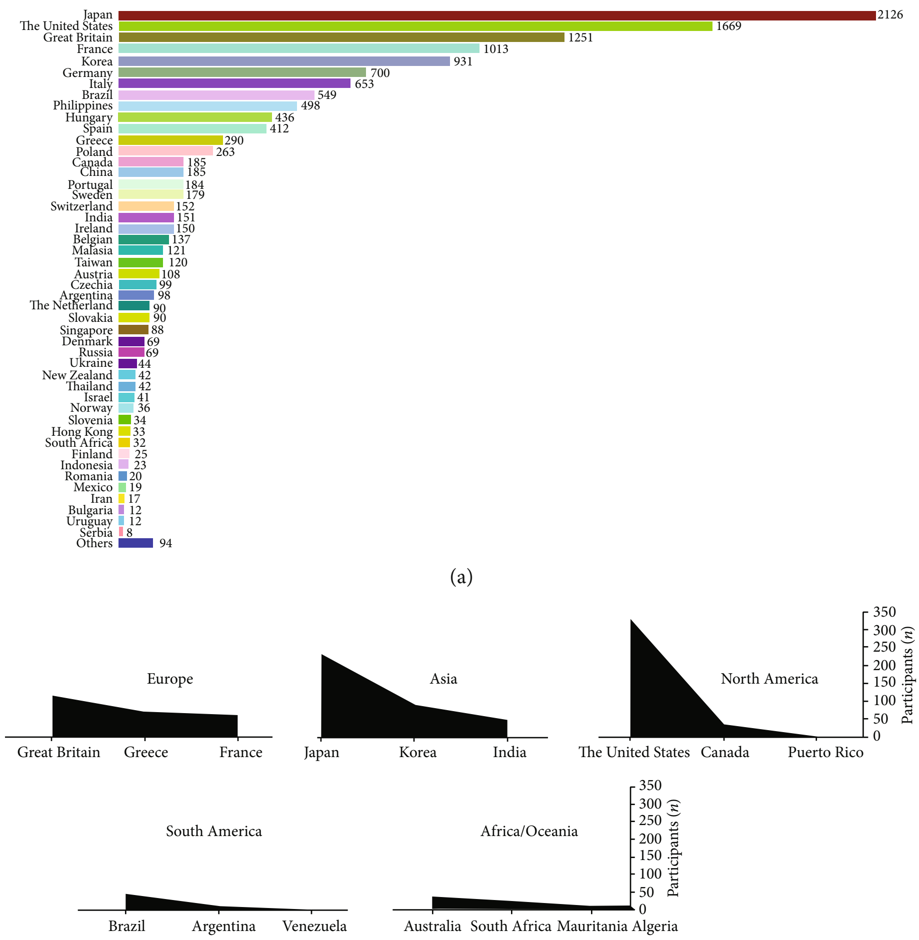
3.3. Age of Peak Performance. The distribution of male runners showed, in the years 2010 to 2020, between 41 and 50 years of age. This was five years older compared to the female distribution where runners were aged between 41 and 45 years. Participation in the top 20 ultramarathoners was less than 1% for runners aged 20 to 25 or over 65 years of age (Figures 4(a) and 4(b)).

When analyzing the age of PP, the multifactorial model for performance showed significant results ($F = 28.613$, $p < 0.001$; $\eta^2 = 0.043$), years ($F = 27.388$; $p < 0.001$; $\eta^2 = 0.020$), and interactions: sex × years ($F = 3.612, p < 0.001$; $\eta^2 = 0.003$). In contrast, there was no *difference* between sexes ($F = 3.616, p = 0.057$; $\eta^2 = 0.001$). For men, there was a reduction in the years 2015 (44.3 ± 8.8 ; $p = 0.005$), 2016 (44.4 ± 8.5 ; $p = 0.011$), 2017 (44.3 ± 8.5 ; $p = 0.002$), 2018 (44.5 ± 8.6 ; $p = 0.010$), 2019 (44.5 ± 8.6 ; $p = 0.016$), and 2020 (44.4 ± 8.3 ; $p = 0.044$) when compared to 2010 (46.1 ± 8.9). Women showed an increase in age in 2019 (46.2 ± 9.4) when compared to 2015 (42.3 ± 8.3 ; $p < 0.001$) and 2016 (42.5 ± 7.9 ; $p = 0.001$) and in the year 2018 (45.5 ± 8.3) to 2015 (42.3 ± 8.3 ; $p = 0.0230$). When there was a difference between the sexes, women were younger in 2014 (43.4 ± 8.5 vs. 45.0 ± 8.8 ; $p = 0.030$), 2015 (42.3 ± 8.3 vs. 44.3 ± 8.8 ; $p = 0.006$), and 2016 (42.5 ± 7.9 vs. 44.4 ± 8.5 ; $p = 0.006$) (Figure 5).

3.4. Performance. When analyzing average velocity over the years, the multifactorial model for performance showed significant results ($F = 14.435, p < 0.001$; $\eta^2 = 0.021$), for sex ($F = 22.722, p < 0.001$; $\eta^2 = 0.002$) and years ($F = 11.712$; $p < 0.001$; $\eta^2 = 0.008$), but no relationships between sex × years ($F = 0.769, p = 0.659$; $\eta^2 = 0.001$). Figure 6(a) shows a reduction in average velocity over the years for male runners from 2015 (5.7 ± 1.5 km/h ; $p < 0.001$), 2016 (5.6 ± 1.5 km/h ; $p < 0.001$), 2017 (5.5 ± 1.5 km/h ; $p < 0.001$), 2018 (5.4 ± 1.6 km/h ; $p < 0.001$), 2019 (5.4 ± 1.6 km/h ; $p < 0.001$), and 2020 (5.4 ± 1.6 km/h ; $p < 0.001$) when compared to the year 2010 (6.1 ± 1.7 km/h). As for women, there was a reduction in the average velocity in 2019 (5.1 ± 1.5 km/h; $p < 0.001$) and 2020 (5.1 ± 1.7 km/h ; $p < 0.001$) when compared to 2012 (5.8 ± 1.7 km/h). When comparing the average velocity between the sexes, women presented a lower speed than men in 2014 and 2019 ($p < 0.001$). In the analysis stratified by distance (Figure 6(b)), women had lower mean speed than men in all stratifications ($p < 0.001$).

When analyzing average velocity stratified by different distances, the multifactorial model for performance showed significant relationships ($F = 8.612, p < 0.001$; $\eta^2 = 0.195$), for sex ($F = 7.495, p = 0.006$; $\eta^2 = 0.001$) and distance ($F = 31.920$; $p < 0.001$; $\eta^2 = 0.334$) but no relationship between sex × distance ($F = 0.871, p = 0.881$; $\eta^2 = 0.010$). Men and women showed higher velocity in distances from 180 to 240 km (6.14 ± 1.47 km/h vs. 5.97 ± 1.48 km/h) when compared to 241 to 300 km (6.0 ± 1.64 km/h vs. 4.59 ± 1.09 km/h ; $p < 0.001$), 301 to 360 km (4.6 ± 1.05 km/h vs. 4.0 ± 1.08 km/h ; $p < 0.001$), and >360 km (4.1 ± 1.20 km/h vs. 4.5 ± 1.09 km/h ; $p < 0.001$), respectively. A negative linear regression (Figures 6(c) and 6(d)) was observed for the velocity of women ($Y = -0.002749 * X + 6.269$; $r = -0.3$; $p < 0.001$) and men ($Y = -0.003743 * X + 6.739$; $r = -0.3$; $p < 0.001$) with increasing distance.

Also, when analyzing the top 10 average velocities over the years, the multifactorial model for performance showed significant effects ($F = 10.442, p < 0.001$), for sex ($F = 20.149, p < 0.001$) and years ($F = 8.600, p < 0.001$), but no relationships between sex × years ($F = 0.885, p = 0.546$). Figure 7 shows no reduction in the average velocity over the years for female runners. When comparing the average velocity between sexes, women presented a lower speed than men in 2014 ($p = 0.008$), 2017 ($p = 0.002$), 2018 ($p = 0.008$) and 2019 ($p = 0.038$). Men reduced average velocity from 2017 (5.7 ± 1.5 km/h; $p = 0.003$), 2018 (5.6 ± 1.6 km/h; $p = 0.001$), 2019 (5.4 ± 1.8 km/h; $p < 0.001$), and 2020 (5.5 ± 1.6 km/h; $p < 0.001$) when compared to the year 2010 (6.1 ± 1.9 km/h).



(b)

Figure 2: Distribution of ultramarathons by nationality and country events. (a) Number of competitors by nationality; (b) top three countries by continent that organized the most competitions.

4. Discussion

The aim of the present study was to analyze the age peak performance progression (PP) and ultramarathon running (UMs) events performed over 180 km. We analyzed 1202 races from the last two decades (2000 to 2020) and individual data from 13,300 runners between the years 2010 to 2020. The results show the following: (i) The continent of Europe hosted the highest number of events in the world; (ii) Japanese nationals were the most common among UMs runners. (iii) The United States stood out as the country that had the most organized UM competitions. (iv) Marathon runs between 180 and 240 km were the most recurrent, especially after 2016, when there was an advance in the number of races over 360 km, run at a lower speed. (v) The number of women finalists in UMs represented a low percentage compared to men. (vi) Men accounted for more than 80% of the runners, showing a reduction in PP from 2015 onwards. (vii) The distribution of ages by age group showed a male PP from 41 to 50 and female from 41 to 45. The concentration in PP age in both sexes occurred on average at 45 years of age.

When we look at the number of competitions organized during the period 2000 to the year 2020, a significant advance was noticed from the year 2010, reaching almost 200 competitions in the year 2019. A drop was also observed in the year 2020, explained by the COVID-19 pandemic, which caused, in addition to the cancellation of major sporting events such as the Tokyo Olympics and the Euro Cup, as well as cancellation of the UMs competitions. Naturally, the restrictive measures adopted by each country, and the closed borders justified the reduction in the number of organized events [11].

4.1. Continent. The highest number of ultramarathoners around the world came from Europe, followed by Asia and North America. Although, when analyzing the country of nationality of the participating athletes, The United States and Japan were the countries with the highest number, the European continent, in addition, hosted the great traditional world competitions, especially in the United Kingdom, France, Germany, and Italy (e.g., Sandstone Way Ultra 200 Km (GBR); Jurasteig Nonstop Ultratrail 230 km (GER); Paris-Colmar (FRA); Tor des Géants—330 km Endurance

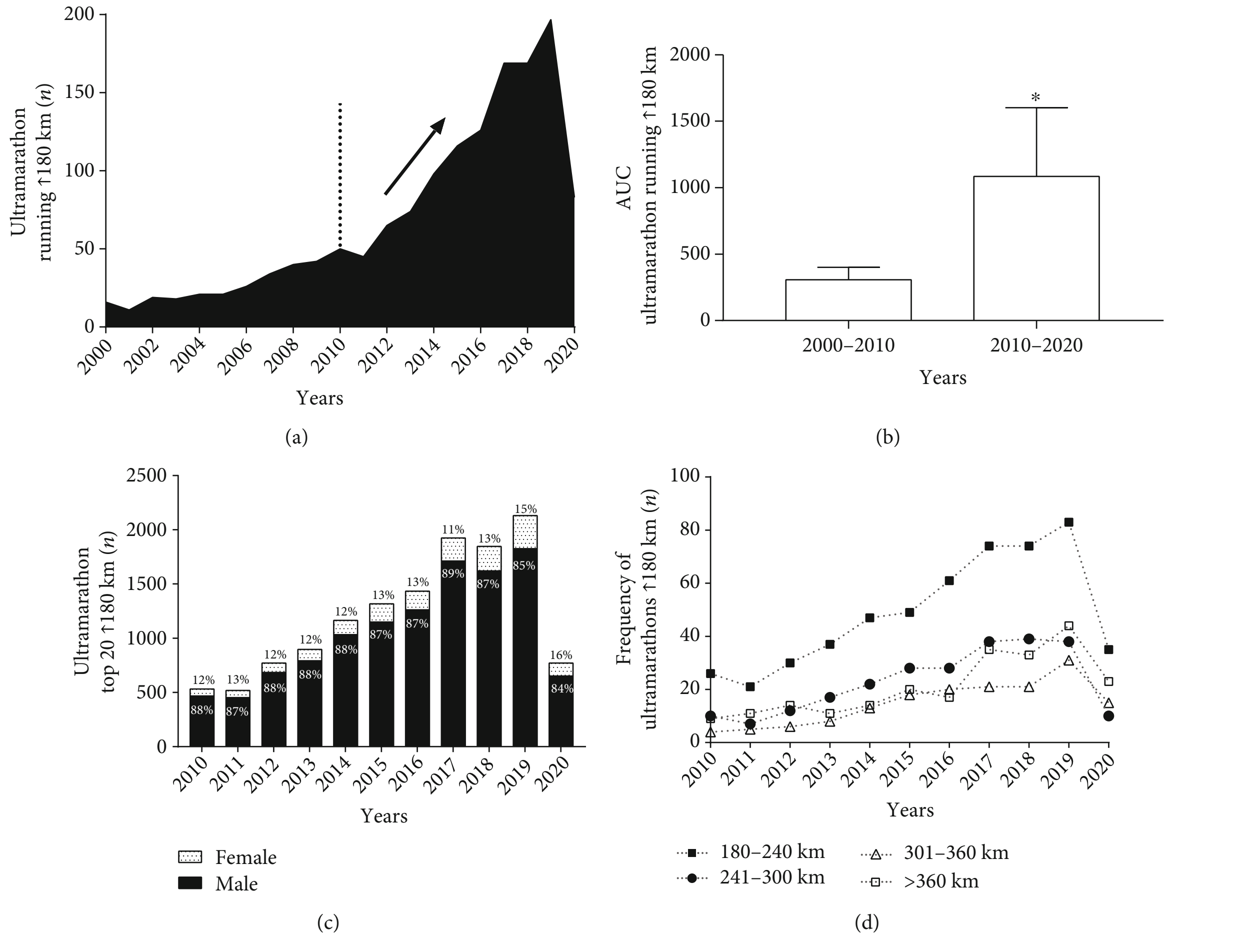


Figure 3: Analysis of the evolution of ultramarathons organized worldwide. (a) Number of ultraraces organized with distances over 180 km; (b) area under the curve; $^{*}p < 0.05$; (c) percentage of finalists; (d) frequency of events organized over 180 km, stratified by distance.

Table 1: Frequency of participation by sex in the top 20 ultramarathons ≥ 180 km, 2010-2021.

Year	Male			Female			Total		
	n_i	N_i	F_i (%)	n_i	N_i	F_i (%)	n_i	N_i	F_i (%)
2010-2011	467	467	4.0	64	64	3.9	531	531	3.9
2011-2012	452	919	7.9	66	130	7.9	518	1.049	7.8
2012-2013	684	1.603	13.8	87	217	13.1	771	1.820	13.6
2013-2014	792	2.395	20.6	104	321	19.4	896	2.716	20.4
2014-2015	1.033	3.428	29.4	131	452	27.3	1.640	3.880	29.1
2015-2016	1.149	4.577	39.3	168	620	37.5	1.317	5.197	39.0
2016-2017	1.261	5.838	50.1	172	792	47.9	1.433	6.630	49.8
2017-2018	1.712	7.550	64.8	211	1.003	60.6	1.923	8.553	64.3
2018-2019	1.620	9.170	78.7	226	1.229	74.3	1.846	10.399	78.1
2019-2020	1.825	10.995	94.4	305	1.534	92.7	2.130	12.529	94.2
2020-2021	651	11.646	100.0	120	1.654	100.0	771	13.300	100.0

n_i: absolute frequency; N_i: accumulated frequency; F_i: accumulated relative frequency.

Trail della Valle d'Aosta (ITA)). This information corroborates the study by Silva [11] highlighting an increase in American, Japanese, German, Italian, and Polish participants in 100 km races over the last 14 years. Japanese runners were highlighted at times for sprint running. The finding that runners from Japan were among the best in the 10 km, half-marathon, marathon, and 100 km ultramarathon running has been previously reported [8]; Japanese participation continued advancing and, also, the number of large, organized UMs. In contrast, Africa, although it is the

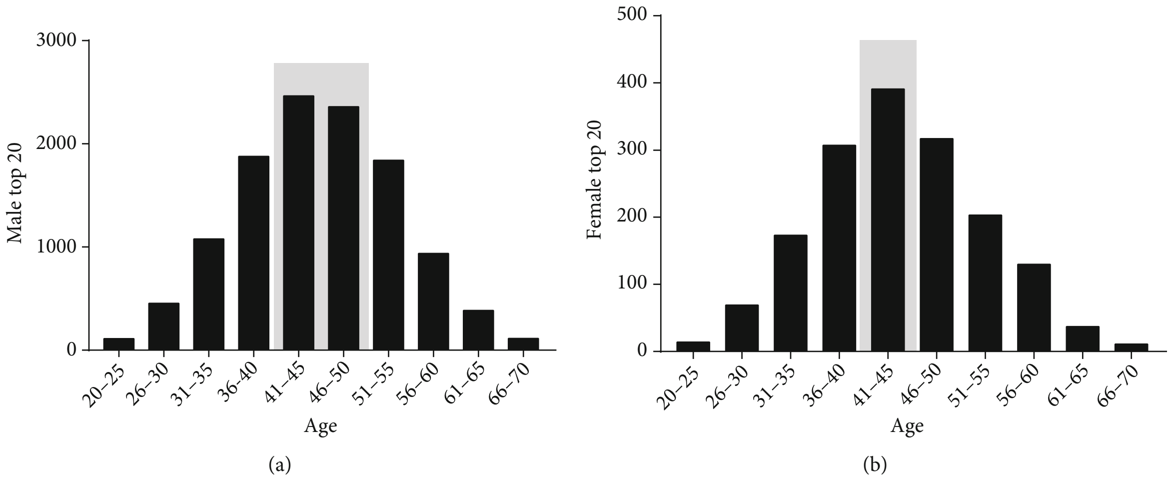


Figure 4: Histograms by age. (a) Histogram of the age of male finalists; (b) histogram of female age.

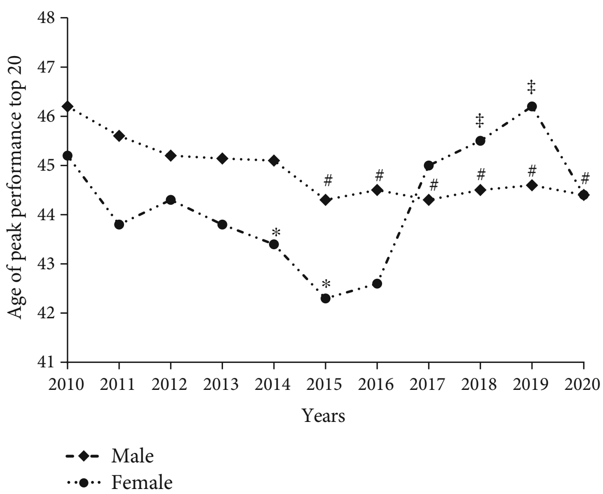


Figure 5: Age of peak performance. Legends: *female vs. male; #men: 2010 vs. 2015, 2016, 2017, 2018, 2019, and 2020; ‡women: 2015 vs. 2018 and 2019. $p < 0.05$.

continent with the highest number of countries and has had the greatest success of East African athletes in long-distance running over the past 40 years (e.g., Kenyan and Ethiopian endurance runners) [12, 13], presented a low number of UM competitions.

When evaluating the quantity of the UM events in a stratified way, a highlight was noted for the courses between 180 and 240 km. Competitions with these specific distances were the most organized, possibly because they had more favorable logistics: these distances can be covered in 1 or 2 days, making them less complex than events organized over multiple days. On the other hand, interestingly, competitions over 360 km began to become common in 2017, a fact that should be further explored. In part, it can be explained by the increase in psychological resilience [9].

4.2. Sex Participation. Males were predominant among the top 20 ultramarathoners in the UMs in all evaluated years. Female representation was also low in events with courses closer to 100 km [14]. However, in marathons, female participation has increased, with proportions similar to males, even in the younger age groups [2]. On the other hand, we can observe over the years that there has been a slight evolution in the number of women runners at UMs, suggesting a possible reduction in the difference in the *speed* of men/women, perhaps explained by cultural changes, social and sporting scenarios favoring female engagement in sport [15].

4.3. Age of Peak Performance. Interestingly, from 2017 onwards, the average age of female participants in the UMs increased by 3 years when compared to 2015. In contrast, from 2015 onwards, the average age of the men decreased by practically 2 years when compared to 2010. In recent years, parallel to the development of training and nutritional variables, ultraendurance running has experienced exponential growth in popularity, with more organized events each year [16]. We believe that competitions equal to or greater than 180 km have accompanied this popularity as well as the tendency towards reduction in the average age of the participants. In addition, many young runners under the age of 19 are participating in 100-km events, especially over the last couple of decades [17].

In general, we observed that the age of PP in 180+ km runs averaged 45 years, 5 years older than 100 km runners [2], 10 years older than the marathon runners, and 20 years older than half-marathon runners [4]. The highest age of peak performance in ultramarathoners compared to that in half-marathoners and marathoners is related to the fact that most of the time, the ultramarathoners have completed many marathon races before participating in a UMs. On the other hand, age of PP found in runs of 180 km and over was similar to what was observed in races of 100 km [2].

Most male participants were in the range of 41 to 50 years old, being older than women by 5 years. Women had a shorter age range, between 41 and 45 years, possibly justified by the fact of greater male representation. However, the PP of men by age was higher than that of women only in 2014, 2015, and 2016. These results are also in

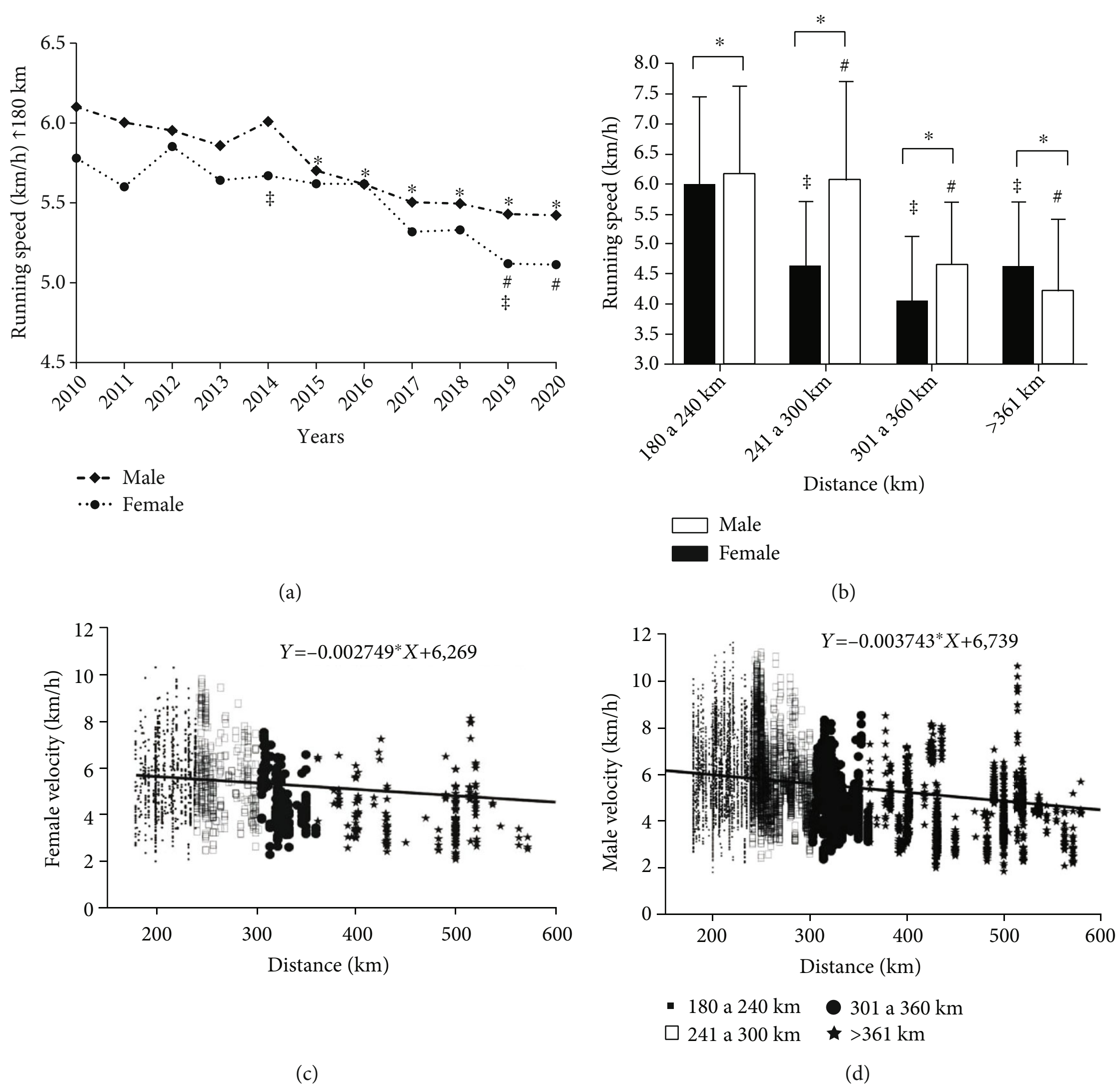


FIGURE 6: Results of performance comparison between the sexes and distance. (a) Average velocity. *Male 2010 vs. 2015, 2016, 2017, 2018, 2019, and 2020; #women 2012 vs. 2019 and 2020; ‡2014 and 2019. Female vs. male. $p < 0.05$. (b) Average velocity stratified by different distances; *male vs. female; $p < 0.001$. #Female 180 to 240 km vs. 241 to 300 km, 301 to 360 km, and >360 km; $p < 0.001$. ‡Male 180 at 240 km vs. 241 at 300 km, 301 at 360 km, and >360km; $p < 0.001$. (c) Velocity correlation stratified by different distances for women; (d) velocity correlation stratified by different distances for men.

agreement with the findings of Romer et al. [18], identifying the average age in the 200 km races for both sexes close to 42 years of age.

4.4. Ultramarathoners' Performance. There was a reduction in running speed among men in the years 2015 to 2020. This trend, although similar for the women runners, as verified by linear regression, was only actually true for the years 2019 and 2020. This reduction can be related to the increase in the number of participants in events with distances above 360 km and average speeds around 4 to 4.5 km/h. As verified by Hoffman et al. [19], the increase in number of runners was not associated with an increase in number of events. These results are explained by changes in the profile of the runners, given that most of them were recreational runners, with objectives of improving their health, quality of life, and not necessarily their performance [20, 21].

An analysis of the top 10 ultramarathoner runners showed that women kept at the same speed over the years. That is, although there was a substantial difference between the top 20 and the top 10 finalists, when comparing running speed, only the first 10 finalists manifested changes in performance pattern. Another fact can also be observed with the increase in the differences between male and female. Significant differences in running performance between the sexes were shown only in the 2014 and 2019 events. Among the top 10 ultramarathoners, the difference in running performance was greater in 2014, 2017, 2018, and 2019, with male athletes doing better than female athlete.

In general, sex differences in endurance sports were ≈12% [22]. A plethora of factors can be associated with performance differences, i.e., anthropometric characteristics, physiological indicators, and training commitment [6, 7]. However, in recent studies woman have reduced the

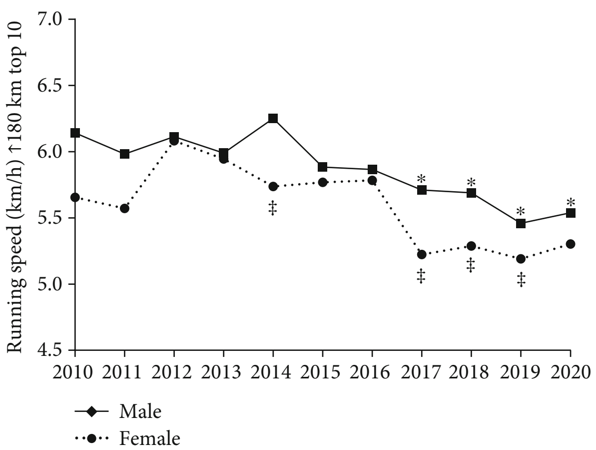


Figure 7: Running top 10 finalist speeds: *male 2010 vs. 2017, 2018, 2019, and 2020; ‡female vs. male 2014, 2017, 2018, and 2019.

performance difference [23]. Another aspect is the decrease in the physiological index associated with endurance performance. For example, the maximum oxygen uptake (VO_2max) or cardiac output decreases with increasing age [24]. Besides this, changes in training commitment, nutritional habits, and body composition alterations can explain these results.

4.5. Limitations and Future. New studies should include more characteristics of runners such as aerobic capacity, muscle mass, fat mass, and experience of training. Although the DUV research source presents a large amount of data and makes it an easy way to check out the global UMs, the data is retrospective. In order to expand the analysis of the performance progression, a comparison with other data and not just with the top 20 finalists is suggested. The stratification of events according to different climatic conditions should be investigated. On the other hand, to our knowledge, this is the first study that has analyzed participation, age peak, and performance progression in UMs with distances longer than 180 km.

4.6. Practical Implications. Although Ethiopia and Kenya runners were the most numerous in the 10 km, half-marathon, and marathon runs, Africans were underrepresented in the UMs races. The number of Japanese ultramarathoners increased. Women had limited representation in the UMs. Men were the fastest in all distance events. This information is of great practical value for coaches who work with distance runners. Being aware of the role that participation, age peak and performance progression can help coaches design exercise programs and make decisions about the most suitable running distance for their trainees. Adapted medical assessment for the older athletes could be useful in avoiding medical events such as sudden cardiac death. For coaches and older athletes preparing for an ultramarathon, specific training plans and nutrition plans for the elderly athletes could be designed.

5. Conclusions

The past decade has seen an increase in the number of ultramarathon running events. The European continent had the highest number, followed by Asia and North America. There was an exponential increase in the participation of men, with a much lower participation of women. The age peak performance to the world's, top 20 finalists, was on average 45 years. Men and women showed higher velocity in distances from 180 to 240 km when compared to 241 to 300 km, 301 to 360 km, and >360 km. The average running speed reduced over the years; this fact is associated with an increase in the number of participants in the events and not specifically related to a decline in athletic performance.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent

Athlete consent was waived due the research concerning the study of publicly available data.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Contributions

RFS, MMSS, and MT are assigned to the conceptualization. RFS, MMSS, DSS, MDJA, and DPMO are responsible for the methodology. FJA, BK, AFS, HN, FMC, GB, GG, and SC did the formal analysis. RFS, MMSS, and MT curated the data. RFS, MMSS, GB, and MT are responsible for the writing—original draft preparation. RFS, GB, FMC, AFS, and GG are responsible for the writing—review and editing. All authors have read and agreed to the published version of the manuscript. Stefania Cataldi and Gianpiero Greco share the last authorship.

Acknowledgments

We would like to thank the Coordination Graduation Program of Physical Education, Federal University of Sergipe (UFS), and the members of Group of Studies and Research of Performance, Sport, Health and Paralympic Sports (GEPEPS) and UFS running club. The English version of this text was revised by Sidney Pratt, Canadian, BA, MAT (The Johns Hopkins University), RSAdip (TEFL—Cambridge University).

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Hindawi
BioMed Research International
Volume 2022, Article ID 2777079, 10 pages
https://doi.org/10.1155/2022/2777079

Research Article

An Intervention Pattern of Family Parent-Child Physical Activity Based on a Smartphone App for Preschool Children during COVID-19

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Received 25 June 2022; Accepted 1 August 2022; Published 22 August 2022

Academic Editor: Stevo Popovic

Objective. Children's lifestyles, behaviors, and educational activities were affected by COVID-19. The preschool children struggled with the challenge of learning at home and avoiding a rapid decrease in physical activity (PA). This study tested the effectiveness of a family-based intervention that integrated the family and preschool based on a smartphone app to improve the moderate-to-vigorous PA (MVPA) and physical fitness of preschool children during COVID-19. *Methods*. This 8-week study was conducted using a quasiexperimental pre- and posttest design with a comparison group. A total of 66 pairs of preschool children (30 boys) and their parents and 44 preschool children (24 boys) and their parents composed the experimental group (EG) and the control group (CG), respectively. PA was measured using a GENEActiv waveform triaxial accelerometer. Children's physical fitness was assessed using a battery test from the Chinese National Measurement Standards on People's Physical Fitness for preschool children. *Results*. Preschool children and their parents in the EG participated in less sedentary ($p < 0.01$) and more light PA ($p < 0.01$) and MVPA ($p < 0.01$) compared with those in the CG at the late PA assessment. The EG significantly improved the mean performance of tennis ball throw ($p < 0.05$), balance beam walk ($p < 0.01$), and continuous jumping on both feet ($p < 0.01$) compared to the CG. *Conclusions*. The family parent-child PA intervention based on a smartphone app can effectively increase the MVPA of preschool children and their parents, reduce sedentary time, and improve preschool children's physical fitness. Overall, the family parent-child PA intervention model based on a smartphone app for preschool children designed in this study is feasible and effective.

1. Background

The coronavirus disease 2019 (COVID-19) pandemic is a public health emergency of international concern [1]. The World Health Organization (WHO) stressed and urged governments of all countries to remain vigilant and fully prepared to implement epidemic prevention measures [2]. COVID-19 has had a significant impact on people's lifestyles and school education activities, especially traditional school-based teaching activities. Schools have adopted a network-based teaching model to reduce the impact of the epidemic on children's learning in which children's learning places have been confined to home. As the teaching environment changes from school to family, guaranteeing the organized physical education curriculum and prescribed physical activity (PA) time is difficult. Consequently, the children's PA levels have significantly declined and not reached the international level [3]. During COVID-19, online physical education methods improved the physical fitness of adolescents [4]. In the last 10 years, several reviews reported that the efficacy of smartphone-based mHealth PA interventions could be considerably improved [5]. However, the studies targeting children or adolescents (age range: 5–19 years) were limited [5].

Higher levels of PA in preschoolers are positively associated with important benefits in physical [6–8], emotional, social, and cognitive domains [9–11] throughout life. Insufficient moderate-to-vigorous PA (MVPA) and prolonged sedentary activity and inactivity are some of the important problems to be solved urgently to promote children's physical health. Studies have pointed out that insufficient PA is an early risk factor for obesity in preschool children, and hence, the PA pattern of preschool children deserves attention [12, 13]. Currently, the epidemic of COVID-19 has brought challenges to the improvement in the PA levels of preschool children. During the epidemic, preschool children's lives and activities have been confined to home, and sports activities organized by teachers and with the participation of their peers are lacking. As a result, ensuring MVPA for preschool children is difficult [3]. The intervention method based on network application can break some obstacles existing in traditional intervention and has the advantages of not being limited by place and time, providing rich activities, and being easily accepted and used by parents and children [14]. A recent formative study has shown that parents are open to using digital applications to support preschool children's PA [15].

The main objective of the present study was to evaluate the effectiveness of a family parent-child PA intervention based on a smartphone app regarding the changes in the objective measurement of the PA of preschool children and their parents. We also investigated the effects of the intervention on the physical fitness of preschool children.

We hypothesized that, compared with children and parents in the control group (CG), the participants in the experimental group (EG) would show significantly greater increases in MVPA from baseline to postintervention time points, and the children in the EG would report higher levels of physical fitness.

2. Methods

2.1. Study Design and Sample. This was a pre- and posttest study with the CG using a quasiexperimental design. The study was conducted for 8 weeks from October 2020 to December 2020. For the sake of epidemic prevention and control in Beijing, the preschoolers did not go to kindergarten during this period and had activities at home. Two first-level public kindergartens were selected in the urban area of Beijing. The inclusion criteria were as follows: (1) availability of one parent and one child being in good health, (2) children's age between 3 and 5 years, and (3) the parent having a smartphone/iPad that could download and install apps and providing consent for themselves and their children to participate. The exclusion criteria were as follows: children who failed to wear the triaxial accelerometer to monitor PA in the experiment or who wore the triaxial accelerometer for fewer than three consecutive days.

Children aged 3–5 years were enrolled in three age-based grade levels. All children were invited to participate in the study. The parents were informed of the study via announcement posters at the beginning of the school year. All parents received consent letters and were asked to provide written consents for their children to participate in the study. No incentive was provided for participation in the study. The study protocol was approved by the ethics committee at the Capital University of Physical Education and Sports (code 2018072001) and registered in the Chinese Clinical Trial Registry (code ChiCTR1800017292).

A power calculation was conducted to estimate the required sample size. The calculations were conducted using G∗Power 3.1.9. Based on the mobile app on parent-child exercises [16], the intervention effect size of MVPA was estimated at $d = 0.3$. With a type I error probability of 0.05 and power of 0.8, the required sample size was calculated as 46. A minimum of 60 children were recruited to account for an estimated accelerometer noncompliance rate of 15% (i.e., cases with insufficient wear time) and a potential dropout rate of 20%. Based on the aforementioned inclusion and exclusion criteria, 110 pairs of eligible participants, including 66 pairs from the EG and 44 pairs from the CG, were enrolled in the final study analysis, meeting the requirements of statistical sample size.

2.2. Description of Intervention

2.2.1. Theoretical Framework in the Intervention Design. The theoretical model used for the intervention was the Socioecological Model (SEM) [17]. This model recognized multiple levels of influence on health behavior and emphasized the complex interplay between individual, environmental, and policy contexts of healthy behavior. The PA habits of younger children were shaped by parents. Following the SEM, the study was designed to target combined parent-child PA.

2.2.2. Intervention Design. The family-based PA intervention program for children and parents was designed by preschool exercise experts and early childhood educators based on SEM theory, physical and mental development characteristics of preschool children, and family environment characteristics. Based on the physical fitness and motor development approach, this intervention program comprised beneficial, enjoyable, and goal-directed family parent-child cooperative PAs, which included six kinds of PAs: running and climbing, jumping, throwing, balance, flexibility, and coordination. Considering the difference in professional sports equipment in the family environment and the cognitive ability of different parents, the intervention program designed in this study was simple and easy to understand. Also, the equipment required was simple and could be replaced by items at home. Parents could adjust it according to the actual situation. In the 8-week intervention cycle, the participants in the EG received 30 min of family PA intervention twice a week. The 8-week PA plan is shown in Table 1.

The study used the official account "YOUXUE UP" loaded on the WeChat app as an online intervention platform to implement family parent-child PA. This official account is an online teaching application platform developed by Beijing YOUXUE Partner Network Technology Co., Ltd., to provide schools, teachers, students, and parents with teacher-student interaction and home-school interaction services. Figure 1 shows the framework of the app-

Table 1: PA intervention plan based on a smartphone app.

Week	Week 1	Week 2	Week 3	Week 4
Content	Bear crawl	Overhand throw	"S" crawl	Ant crawl race
	Obstacle courses	Catch with both hands	Lying leg raise	Seated knee tucks
	Shuttle run	Catch with a container	Jump over rope	Shuttle run
	Ski jump	Jump with a ball squeeze	Frog jump	Bunny hop
	Cross jump	Jump forward and backward	Jump lunges	Burpee
	High knees in place	Hopscotch	Cross jump	Multidirectional run
	Standing fly	Fun toy (signal)	Walk rope	Stand on each leg
Week	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Content	Jump-crawl combination	Spider crawl	Overhand throw	Jump squat
	Side slide	Seated knee tucks	Relay race	Jump jacks
	Jump jacks	Log roll	Lateral high knee	Jump lunges
	Jump lateral	High five lunge jump	Burpee	High knees and clap
	Hop	Squat punch	Standing leg curl	Fun chair (signal)
	Catch the tail	Single leg squat	"S" backward run	Jump obstacle and throw
	Shoulder presses	Parent-child yoga	Standing trunk twist	Duck walk

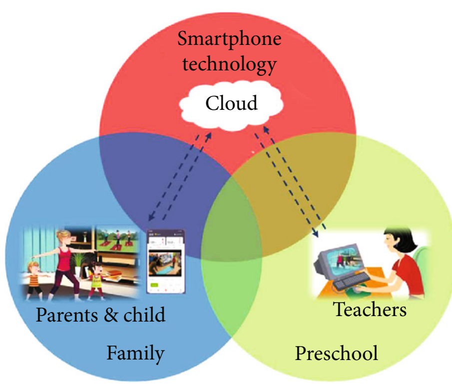

Figure 1: Framework of the family parent-child PA intervention based on a smartphone app.

based family parent-child PA intervention designed for this study.

Before starting the experimental intervention, 10 children and parents were invited to conduct a 1-week preexperiment. They were asked through a symposium about their experience in using the WeChat official account "YOUXUE UP" and their suggestions on the difficulty of designing the exercise content. The information obtained from the preexperiment was used to modify the process and practice content of the experimental intervention to improve the participation of the individuals. Before the formal experimental intervention, the researchers established a class through the WeChat official account "YOUXUE UP" and sent a class invitation link to the parents in the EG. After the parents registered successfully, they entered the class group. In addition, the researchers made short videos of each PA content and practiced precautions in preparing for the intervention. During the experimental intervention, the researchers sent preprepared practice tasks (short videos) to parents on time every Tuesday and Saturday (16:00–19:00 p.m.) through the WeChat official account of "YOUXUE UP." The parents viewed through the official account, led their children to practice together at home according to the video requirements, and were required to record the practice process as a video and upload it. After the researchers received the feedback, they commented and scored in a timely manner. The parents could ask questions through the "mutual evaluation" of the official account. The researchers replied in time after receiving the feedback, and parents who had not uploaded the tasks received task reminders. According to the feedback, the researchers praised the children who completed all the tasks every week and provided small rewards as encouragement. Figure 2 shows a screenshot of parent feedback on the completion of family parent-child PA.

2.2.3. Control Conditions. During the experimental intervention period, the parents and children in the EG performed family parent-child PA based on the WeChat official account of "YOUXUE UP." In the CG, the parents and children did not register the WeChat official account of "YOUXUE UP" to obtain the content of family parent-child PA. After the experiment, the parents in the CG register into the WeChat official account of "YOUXUE UP" free of charge to obtain resources for family parent-child PA.

2.3. Study Measurements. The main outcome variables of the study are shown in Table 2.

2.3.1. Anthropometry. Height (cm) and weight (kg) were measured without shoes and with light, sports clothing with a stadiometer (SECA 213, Hamburg, Germany) and a balance scale (MIUI 2, Anhui, China), respectively. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

2.3.2. Primary Outcomes. The PA of preschool children and their parents was measured using a GENEActiv waveform

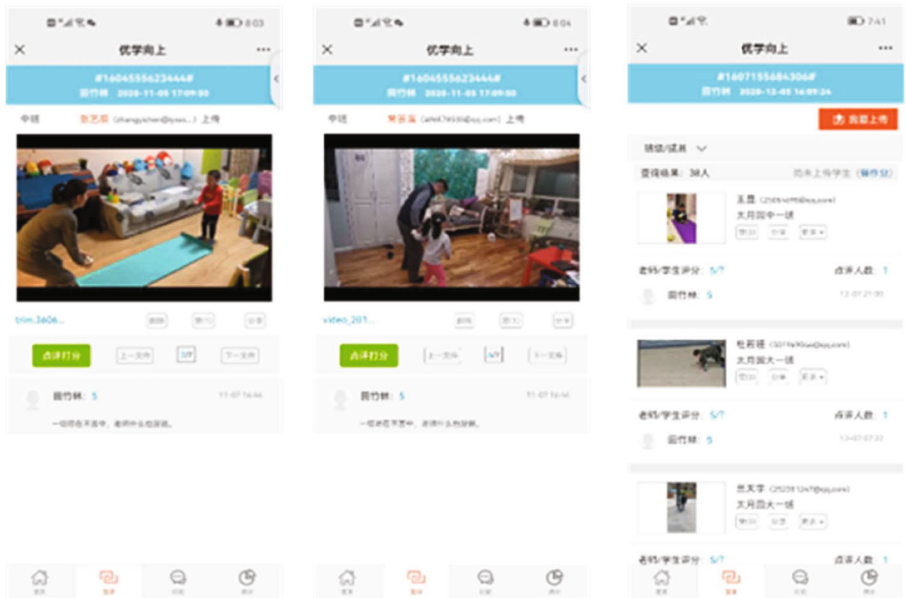

Figure 2: Screenshot of parent feedback on the completion of family parent-child PA.

Table 2: Description of study outcome measurement.

Measure(s)	Purpose	Instrumentation
PA	To measure the levels of PA for preschool children and their parents [18].	PA was measured using a GENEActiv waveform triaxial accelerometer (ActivInsights Ltd., Cambridge, UK).
Weight and height	To calculate BMI (weight in kg/height in m^2) as a measure of anthropometrics.	Weight using a stadiometer (SECA 213, Hamburg, Germany); height using a balance scale (MIUI 2, Anhui, China).
Physical fitness	To measure the levels of physical fitness for preschool children [19].	Standing long jump test for lower-body muscular strength, tennis ball throw test for upper-limb muscular strength, continuous jump on both feet test for coordination and lower-body muscular strength, 2×10 m SRT test for speed agility, sit-and-reach test for flexibility, and balance beam walk test for dynamic balance.

Note: BMI: body mass index; PA: physical activity; SRT: shuttle run test.

triaxial accelerometer (ActivInsights Ltd., Cambridge, UK). The parents of preschool children were informed about the precautions for wearing the GENEActiv accelerometer before testing to ensure that the accelerometer was properly worn. Preschoolers and their parents were required to wear the accelerometer on the wrist of the nondominant hand for seven consecutive days at two different test time points. The data for baseline PA were collected 1 week before the intervention (week 0), whereas the data for late PA were collected in weeks 6–7 of the intervention (week 6 or week 7). Due to the young age of preschool children, it was difficult to wear the accelerometer for a long time. If the valid data of the participant's accelerometer reached more than 3 days (including 1 day on weekends and 2 days during the week), it was included in the final data analysis. A total of 123 pairs of preschool children and their parents wore accelerometers, and 8 pairs of preschool children and their parents were excluded from incomplete accelerometer data records, resulting in 115 pairs of valid data. For each epoch (seconds), the motion data (activity counts) were added, recorded, processed, and analyzed. Cumulative activity counts were categorized by intensity into sedentary, light PA (LPA), and MVPA. The acquired data (.bin format) were processed by R software using R-Markdown provided by ActivInsights Ltd. For PA cut-points, the preschoolers used published cut-points [18], whereas the parents used R-Default cut-points in Markdown.

2.3.3. Secondary Outcomes. A battery test from the Chinese National Measurement Standards on People's Physical Fitness for young children was used to assess children's physical fitness, which was defined as the body's ability to achieve optimal levels of physical performance in dealing with physiological stress to the body [19]. This normed assessment was validated in Chinese preschool-age children and used in the Chinese national fitness surveys [20]. The measurements included the standing long jump test for lower-body muscular strength, tennis ball throw test for upper-limb muscular strength, continuous jump on both feet test for coordination and lower-body muscular strength, 2×10 m SRT test for speed agility, sit-and-reach test for flexibility, and balance beam walk test for dynamic balance. The

Table 3: Baseline demographic characteristics of participants ($N = 110$).

Variables	EG ($n = 66$)	CG ($n = 44$)	p
Age (year)	4.16 ± 0.55	4.33 ± 0.43	0.118
Sex (male/female)[a]	30/36	24/20	0.350
Height (cm)	107.51 ± 4.35	106.33 ± 6.17	0.276
Weight (kg)	18.17 ± 1.63	18.22 ± 1.92	0.873
BMI (kg/m²)	15.72 ± 1.07	16.2 ± 2.16	0.174

Note: EG: experimental group; CG: control group; [a]the difference between the two groups tested using the chi-squared test.

physical fitness indicators of children were tested 1 week before the intervention and 1 week after the intervention, and these tests were completed in kindergarten.

2.4. Statistical Analysis. SPSS 24.0 software (IBM Corporation, NY, USA) was used for statistical analysis of all data. The independent-sample t-test (height, weight, and BMI) and the chi-squared test (sex) were used to test for the differences in demographic variables. Then, 2 (group : EG and CG) × 2 (time : pre-and posttest) repeated-measures analysis of variance was used to test the difference in the effect of experimental intervention. When the group×time interaction or the time and group main effects were significant, pairwise comparisons with statistical differences were further performed by simple-effects analysis. The partial η^2 ($\eta_p{}^2$) was used as a measure of effect size and divided into small (0.01), medium (0.03), and large (0.14) effects according to Cohen's study [21]. A p value < 0.05 indicated a significant difference. All data were presented as the mean ± standard deviation ($M \pm \text{SD}$).

3. Results

3.1. Characteristics of the Study Sample. In this study, 135 parents agreed to participate in the experiment, with a participation rate of 91.11%. A total of 110 pairs of participants participated in the pre- and posttests, and the dropout rate for the experiment was 10.57%. Further, 66 preschool children (age 4.16 ± 0.55 years, 45% boys) and their parents in the EG and 44 preschool children (age 4 ± 0.47 years, 55% boys) and their parents in the CG completed all the tests. Figure 1 shows the participation process. The average weekly task completion feedback rate of the EG families was 65%. None of the participants experienced injuries related to the test or training content throughout the study period. This study analyzed the data of children ($N = 110$) who participated in the pre- and postexperiment tests. At baseline, no significant differences were found in demographic characteristics and primary and secondary outcome variables between the EG and CG (Table 3). Figure 3 presents a flowchart of the participant selection process.

3.2. Intervention Effects on Primary Outcomes. Repeated-measures variance results showed that preschool children's sedentary ($F(1, 105) = 37.59, p < 0.01, \eta_p{}^2 = 0.26$), LPA ($F(1, 105) = 22.37, p < 0.01, \eta_p{}^2 = 0.18$), and MVPA ($F(1, 105) = 347.86, p < 0.01, \eta_p{}^2 = 0.77$) had significant interaction effects. A simple-effects analysis showed that the preschool children in the EG participated in less sedentary ($p < 0.01$) and more LPA ($p < 0.01$) and MVPA ($p < 0.01$) compared with those in the CG after the intervention. Compared with that at the baseline PA assessment, the preschool children in the EG participated in less sedentary ($p < 0.01$) and more LPA ($p < 0.01$) and MVPA ($p < 0.01$) at the late PA assessment, but no significant change was observed in the CG ($p > 0.05$) (Table 4).

Repeated-measures variance results showed that parents of preschool children with sedentary ($F(1, 105) = 44.82, p < 0.01, \eta_p{}^2 = 0.3$), LPA ($F(1, 105) = 17.36, p < 0.01, \eta_p{}^2 = 0.14$), and MVPA ($F(1, 105) = 308.97, p < 0.01, \eta_p{}^2 = 0.75$) had significant interaction effects. The simple-effects analysis showed that, compared with the CG, the parents of the preschool children in the EG participated in less sedentary ($p < 0.01$) and more LPA ($p < 0.01$) and MVPA ($p < 0.01$) compared with those in the CG at the late PA assessment. Compared with that at the baseline PA assessment, the parents of the preschool children in the EG participated in less sedentary ($p < 0.01$) and more LPA ($p < 0.01$) and MVPA ($p < 0.01$) at the late PA assessment. However, no significant change was noted in the CG ($p > 0.05$) (Table 4).

3.3. Intervention Effects on Secondary Outcomes. Repeated-measures variance results showed that preschool children's standing long jump ($F(1, 105) = 17.98, p < 0.01, \eta_p{}^2 = 0.15$), tennis ball throw ($F(1, 105) = 8, p < 0.01, \eta_p{}^2 = 0.08$), 2×10 m SRT ($F(1, 105) = 14.93, p < 0.01, \eta_p{}^2 = 0.12$), and balance beam walk ($F(1, 105) = 19.05, p < 0.01, \eta_p{}^2 = 0.15$) had significant interaction effects. The simple-effects analysis showed significantly greater improvements in the mean performances of tennis ball throw ($p < 0.05$) and balance beam walk ($p < 0.01$) in the EG after intervention, as compared to the CG. Regarding the mean within-group changes, both groups significantly increased the mean of standing long jump, tennis ball throw, 2×10 m SRT, and balance beam walk from pre- to posttests ($p < 0.05$). In addition, the results showed a significant group main effect of continuous jumping on both feet ($F(1, 105) = 5.57, p < 0.05, \eta_p{}^2 = 0.05$). The simple-effect analysis showed significantly greater improvements in the mean performances of continuous jumping on both feet in EG after intervention, as compared to the CG ($p < 0.01$). With respect to mean within-group changes, EG significantly increased the mean of continuous jumping on both feet from pre- to posttests ($p < 0.01$), but not in CG ($p > 0.05$). Besides that, no significant interaction and main effects were found for sit-and-reach (Table 5).

4. Discussion

This study explored the feasibility and effectiveness of an online platform-based PA intervention model for preschool children's families during the COVID-19 epidemic. In the case of school suspension during the epidemic period, the content of family sports activities suitable for the physical

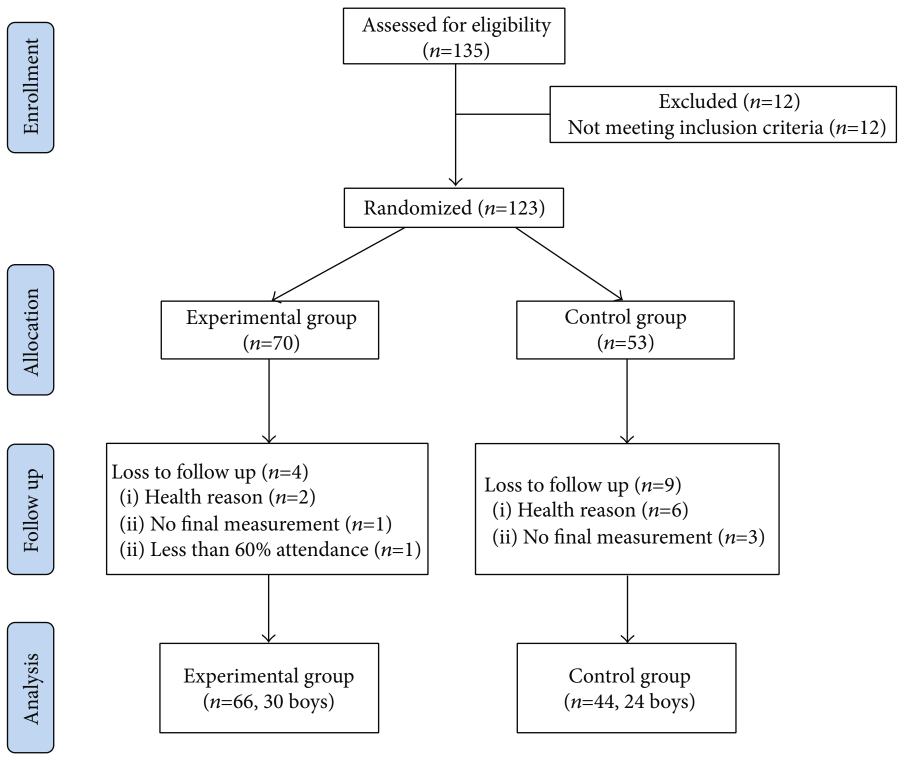

Figure 3: Flowchart of the participant selection process.

and mental development of preschool children was provided to parents to improve the level of MVPA and physical health of preschool children using the model based on the online platform. The main findings of this study were that the family PA intervention based on a smartphone app effectively reduced the sedentary behavior of preschool children and their parents, improved their LPA and MVPA, and effectively improved preschool children's physical fitness, such as muscle strength, coordination, speed-agility, and balance.

A recently published review analyzed nearly 6 years of research published on digital intervention strategies to improve PA in preschoolers. It found that implementing child-centered digital PA interventions in kindergartens significantly improved physical activity in preschoolers, but implementing digital PA interventions monitored only by parents was not effective in improving PA levels in preschoolers [22]. The main reason for this result was that the parents played only a supervisory role in the interventions included in the analysis and did not participate in the practice with their children through the same intervention. Another possible reason was the use of subjective measurement tools to measure PA, which might be missed by subjective assessments due to the typical short-term, discontinuous PA of preschoolers. Objective measures may be more conducive to obtaining accurate data on the PA of preschoolers. A previous review also indicated that an objective accelerometer should be used to assess the PA levels of preschool children during PA intervention [23]. In this study, the designed family PA intervention plan needed to be completed by parents and children together, and the designed activities were more interesting. The participation rate in the EG reached 94%, which was widely praised by parents and children. Studies have shown that positive emotions are more conducive to improving children's enthusiasm for participation, and the fun and pleasure obtained during sports could encourage preschool children to participate more actively in PA [24, 25]. Moreover, the study also used an objective measurement tool to measure the PA of the participants, ensuring the reliability of the result data, which was also an important reason for the significant effect of this study.

In addition, the findings of the present study showed that the family PA intervention based on a smartphone app effectively improved preschool children's performance on standing long jump, tennis ball throw, 2×10 m SRT, balance beam walk, and continuous jump on both feet but had no significant effect on sit-and-reach. At the same time, this study also discovered that the preschool children in the CG have achieved significant improvement in standing long jump, tennis ball throw, 2×10 m SRT, and balance beam walk from pre- to posttests. Previous studies showed that some physical fitness in the CG after the intervention also significantly improved [26, 27], indicating that the current routine PA implemented in kindergartens had a certain effect in terms of improving some physical fitness of preschool children. However, when it comes to changes in preschool children's physical fitness, it is critical to evaluate not only the statistically significant changes across time but also the practical implications for results. The results acquired in this study demonstrated that the performances of tennis ball throw, balance beam walk, and continuous jump on both feet of preschool children in the EG were significantly better

Table 4: Effects of the intervention on primary outcomes according to group ($N = 110$).

Variables	Baseline PA	Late PA	Mean difference [95% CI][b]	η_p^2
Sedentary (min)[%]				
CG	146.89 (25.19)	143.91 (28.87)	-2.97 [-13.44 to 7.5]	0
EG	148.31 (25.61)	102.45 (25.04)	-45.85 [-54.65 to -37.24][##]	0.51
Mean difference [95% CI][a]	1.42 [-7.65 to 12.3]	-41.46 [-51.39 to -30.16][**]		
LPA (min)[%]				
CG	100.6 (30.9)	100.72 (25.06)	0.13 [-9.66 to 10.6]	0
EG	101.32 (29.53)	133.47 (30.48)	32.15 [23.69 to 40.15][##]	0.36
Mean difference [95% CI][a]	0.72 [-11.68 to 12.24]	32.74 [20.77 to 42.69][**]		
MVPA (min)[%]				
CG	7.87 (2.43)	8.32 (2.65)	0.46 [-0.86 to 1.75]	0
EG	7.63 (2.91)	24.06 (4.12)	16.43 [15.37 to 17.5][##]	0.9
Mean difference [95% CI][a]	-0.23 [-1.53 to 0.57]	15.74 [14.09 to 16.93][**]		
Sedentary (min)[%]				
CG	166.3 (18.58)	163.92 (19.6)	-2.38 [-12.4 to 8.16]	0
EG	163.66 (22.27)	116.89 (30.8)	-46.77 [-55.33 to -38.55][##]	0.54
Mean difference [95% CI][a]	-2.64 [-10.51 to 5.53]	-47.02 [-57.7 to -36.92][**]		
LPA (min)[&]				
CG	107.32 (22.73)	108.99 (23.1)	1.67 [-7.84 to 11.06]	0
EG	107.39 (23.28)	134.6 (25.82)	27.22 [19.54 to 34.97][##]	0.32
Mean difference [95% CI][a]	0.07 [-8.81 to 9.17]	25.61 [16.23 to 35.43][**]		
MVPA (min)[&]				
CG	4.77 (2.98)	5.72 (1.98)	0.95 [-0.33 to 2.2]	0.02
EG	5.15 (2.8)	20.51 (4.18)	15.37 [14.35 to 16.41][##]	0.89
Mean difference [95% CI][a]	0.37 [-0.77 to 1.45]	14.8 [13.45 to 16.12][**]		

Values are the observed mean (SD); all comparisons are adjusted for sex, age, and BMI. Note: CG: control group; EG: experimental group; PA: physical activity; LPA: light physical activity; MVPA: moderate-to-vigorous physical activity; [%]preschool children; [&]parent; [a]mean between-group difference with 95% confidence interval based on estimated marginal means adjusted for sex, age, and BMI; [b]mean within-group changes with 95% confidence interval based on estimated marginal means adjusted for sex, age, and BMI; η_p^2: partial eta squared; $^{**}p < 0.01$ difference between CG and EG; $^{##}p < 0.01$ difference between pre- and posttest.

than those in the CG ($p < 0.05$) after intervention. In addition, preschool children in the EG improved significantly more than those in the CG on standing long jump, tennis ball throw, continuous jump on both feet, 2×10 m SRT, and balance beam walk from pre- to posttests (Table 5). These findings were similar to previous results [20, 26, 28]. A recent meta-analysis confirmed that the PA interventions in preschool children produced positive changes in lower-body strength and speed-agility [28]. Macak et al. showed that the daily PA designed for preschool children effectively improved their upper- and lower-body strength [26]. Zhou et al. pointed out that the policy-driven, multiagent participation in PA intervention effectively improved preschool children's physical fitness such as muscle strength, agility, balance, and coordination [20]. In this study, the preschool children in the EG showed significant improvements in muscle strength, coordination, speed-agility, and balance, mainly because the designed family parent-child sports activities included strength, motor coordination, stability, locomotor, and object control (e.g., frog jump, hopscotch, stand on each leg, spider crawl, and overhand throw), which effectively stimulated the physical development of preschool children. However, it should be noted that this intervention did not improve flexibility in preschool children, which was similar to the findings of Macak et al. [26]. Studies showed that flexibility decreased with age, and this decline was caused not only by aging-related changes but also by a lack of training in this flexibility, which can be maintained or improved by training in specific ways [29, 30]. Therefore, this study did not report that the possible reason for the improvement in preschool children's flexibility was due to the inclusion of less relevant exercises while designing the activities, which also needs to be improved in future research.

5. Strengths and Limitations of the Study

This study had several strengths. First of all, in the case of epidemic prevention and kindergarten suspension, an online platform-based parent-child PA intervention model for families with preschool children was established. Also, the family parent-child PA exercises were provided to parents through a smartphone app, which effectively improved the level of MVPA and physical fitness of preschool children.

Table 5: Effects of the intervention on secondary outcomes according to group ($N = 110$).

Variables	Pretest	Posttest	Mean difference [95% CI][b]	η_p^2
Standing long jump (cm)				
CG	78.4 (13.9)	81.39 (12.86)	2.99 [0.53 to 5.62][#]	0.05
EG	76.07 (14.32)	86.29 (10.14)	10.23 [8.1 to 12.24][##]	0.47
Mean difference [95% CI][a]	-2.33 [-1.14 to 9.26]	4.9 [-0.83 to 6.89]		
Tennis ball throw (m)				
CG	3.31 (1.13)	3.63 (1.15)	0.32 [0 to 0.65][#]	0.04
EG	3.53 (1.28)	4.46 (1.43)	0.93 [0.66 to 1.19][##]	0.32
Mean difference [95% CI][a]	0.22 [-0.31 to 0.56]	0.83 [0.23 to 1.22][**]		
Continuous jump on both feet (s)[¥]				
CG	8.94 (3.18)	8.52 (2.99)	-0.41 [-1.11 to 0.31]	0.01
EG	7.79 (2.93)	6.74 (2.07)	-1.05 [-1.63 to-0.48][##]	0.11
Mean difference [95% CI][a]	1.15 [-2.32 to 0.02]	1.79 [-2.74 to-0.83][**]		
2 × 10 m SRT (s)[¥]				
CG	9.01 (1.53)	8.42 (1.26)	-0.58 [-0.82 to-0.19][##]	0.09
EG	9.13 (1.72)	7.88 (0.98)	-1.25 [-1.56 to-1.05][##]	0.49
Mean difference [95% CI][a]	0.12 [-0.06 to 0.96]	-0.55 [-0.71 to 0.01]		
Sit-and-reach (cm)				
CG	11.36 (3.27)	10.92 (2.25)	-0.44 [-1.73 to 0.6]	0.01
EG	10.7 (4.42)	10.38 (3.8)	-0.32 [-1.19 to 0.71]	0
Mean difference [95% CI][a]	-0.66 [-2.58 to 0.49]	-0.54 [-1.97 to 0.53]		
Balance beam walk (s)[¥]				
CG	13.83 (5.32)	11.68 (4.47)	-2.15 [-3.41 to-0.64][##]	0.07
EG	15.01 (6.49)	9.11 (3.59)	-5.9 [-7.11 to-4.86][##]	0.52
Mean difference [95% CI][a]	1.18 [-0.36 to 4.03]	-2.56 [-3.54 to-0.71][**]		

Values are the observed mean (SD); all comparisons are adjusted for sex, age, and BMI. Note: CG: control group; EG: experimental group; [¥]reverse scoring; [a]mean between-groups difference with 95% confidence interval based on estimated marginal means adjusted for sex, age, and BMI; [b]mean within-group changes with 95% confidence interval based on estimated marginal means adjusted for sex, age, and BMI; η_p^2: partial eta squared; $^{*}p < 0.05$ difference between CG and IG; $^{**}p < 0.01$ difference between CG and EG; $^{\#}p < 0.05$ difference between pre- and posttest; $^{\#\#}p < 0.01$ difference between pre- and posttest.

In addition, the family PA intervention program designed in this study was interesting and interactive and was deeply liked by preschool children and their parents, which was important for discovering positive intervention effects. Finally, this study used a triaxial accelerometer for the objective measurement of PA, which guaranteed the objectivity and accuracy of the PA results [23].

There were several weaknesses in the study. First, there was no follow-up to examine if the changes in physical activity and physical fitness were sustainable beyond the 8-week intervention. Second, the study used a nonrandomized design, and the sample size was relatively small. Third, this family-based PA was delivered in an unstructured context and nonprofessional organization. Although the applied programs were well designed and properly controlled, parents would still have to be fenced off by the expertise of their application, because they lack professional knowledge and skills in physical education. This refers primarily to the organizational aspect of the activity but certainly also to the dynamic and kinematic structure of individual exercises. Namely, it is known that this is the period of children's growth which is specific for numerous morphofunctional changes. Certainly, each exercise would have to have a specific application in terms of starting position, amplitude of movement, pace of execution, dosage, etc. Moreover, it is known how many harmful effects the phones themselves and their use near the youngest can produce, but now, it is being promoted as a transmitter of certain physical activity programs, which could leave a psychological effect on children in terms of highlighting the smartphone as a necessary tool for many life activities.

Besides that, the generalizability of our findings is limited due to the fact that this study was delivered to Chinese city families. Therefore, future research should include families who live in the countryside or in a cross-cultural context. Meanwhile, future research and policymakers should also aim to strengthen specifically targeting parents and children who are inactive or are at risk of health issues.

6. Conclusions

In the case of epidemic prevention and control and kindergarten suspension, the family parent-child PA intervention model for preschool children based on a smartphone app can effectively increase the MVPA of preschool children and their parents, reduce their sedentary time, and improve preschool children's physical fitness, such as muscle strength, coordination, speed-agility, and balance. Overall, the family parent-child PA intervention model based on a smartphone app for preschool children designed in this study is feasible and effective.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Ethical Approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Capital University of Physical Education and Sports (code 2018072001) and registered in the Chinese Clinical Trial Registry (code ChiCTR1800017292).

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authors' Contributions

Xiaowei Han and Zhulin Tian contributed equally to this work.

Acknowledgments

The authors thank the preschoolers and their parents who participated in this study. We also thank the kindergarten leaders and teachers who were invited to participate in this study. This work was supported by the National Social Science Fund of China (Grant number 18BTY074).

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Hindawi
BioMed Research International
Volume 2022, Article ID 2130993, 10 pages
https://doi.org/10.1155/2022/2130993

Review Article

Effects of Short- and Long-Term Detraining on Maximal Oxygen Uptake in Athletes: A Systematic Review and Meta-Analysis

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Received 22 November 2021; Revised 24 April 2022; Accepted 19 July 2022; Published 16 August 2022

Academic Editor: Bojan Masanovic

$\dot{V}O_2$max, a gold standard for evaluating cardiorespiratory fitness, can be enhanced by training and will gradually decrease when training stops. This study, which followed the Cochrane Collaboration guidelines, is aimed at assessing the effect of short- and long-term detraining on trained individuals' $\dot{V}O_2$max through a systematic review and meta-analysis and performed a subgroup analysis to evaluate the effects of different ages, detraining formats, and training statuses on $\dot{V}O_2$max variation between short- and long-term training cessation. Web of Science, SPORTDiscus, PubMed, and Scopus, four databases, were searched, from which 21 of 3315 potential studies met the inclusion criteria. Significant decreases in $\dot{V}O_2$max were identified after short-term training cessation (ES = −0.62 [95% CI -0.94; -0.31], $p < 0.01$; within-group $I^2 = 35.3\%$, Egger's test = −1.22, $p = 0.335$) and long-term training cessation (ES = −1.42 [95% CI -1.99; -0.84], $p < 0.01$; within-group $I^2 = 76.3\%$, Egger's test = −3.369, $p < 0.01$), which shows that the detraining effect was found to be larger on $\dot{V}O_2$max in long-term training cessation than in short-term training cessation ($Q = 6.5$, $p = 0.01$). However, there was no significant difference regarding $\dot{V}O_2$max change between 30-90 days detraining and larger than 90 days detraining ($Q = 0.54$, $p = 0.46$) when conducting subgroup analysis. In addition, younger (<20) individuals showed a greater reduction in $\dot{V}O_2$max after long-term detraining than adult individuals ($Q = 5.9$, $p = 0.05$), and athletes with higher trained-state $\dot{V}O_2$max showed a significant decline in $\dot{V}O_2$max after long-term detraining compared with the lower trained-state group ($Q = 4.24$, $p = 0.03$). In conclusion, both short- and long-term training cessation have a detrimental effect on $\dot{V}O_2$max, and a greater impact on $\dot{V}O_2$max was found in long-term training cessation compared to short-term training cessation; however, there was no significant change in $\dot{V}O_2$max when the duration of training cessation was more than 30 days. To buffer the detrimental effects of detraining, especially long-term training cessation, performing some physical exercise during training cessation can effectively weaken detraining effects. Thus, to prevent athlete's $\dot{V}O_2$max from decreasing dramatically from detraining, athletes should continue performing some physical exercise during the cessation of training.

1. Introduction

Maximal oxygen uptake ($\dot{V}O_2$max) is defined as the maximal rate at which oxygen can be taken up and utilized by the body during high-intensity exercise. Generally, $\dot{V}O_2$max is considered the most effective tool to measure the functionality of the human cardiovascular system [1, 2] and an effective indicator to explain individual cardiorespiratory health [3]. In addition, $\dot{V}O_2$max is a determinant of endurance performance for athletes [4] and one of the standard methods to evaluate the effects of aerobic training on athletes. Sports training and physical exercise are effective means to improve and maintain $\dot{V}O_2$max and have been widely verified in healthy [5], obese or overweight [6, 7], and athlete populations [8, 9]. However, the adaptability of $\dot{V}O_2$max obtained through training is reversible. It will diminish when the training stimulus disappears or decreases significantly [10]. The cessation of training reduces or removes the training stimulus and leads to the loss of anatomical, physiological, and performance training adaptability, which is defined as a detraining effect. The detraining effect on $\dot{V}O_2$max was related to the periods of training cessation, and the duration of the training cessation can be categorized as a short-term (less than four weeks) or long-term (more than four weeks) period in a previous study [10, 11]. Mujika and Padilla [10, 11] summarized some research findings that $\dot{V}O_2$max for highly trained athletes decreased by 4-14% after short-term detraining but decreased by 6-20% after long-term detraining. Although long-term detraining seems to have a greater impact on $\dot{V}O_2$max than short-term detraining, the lack of effective comparison methods makes it unclear how the detraining length affects athletes' $\dot{V}O_2$max.

The high $\dot{V}O_2$max level results from long-term regular exercise to benefit the cardiovascular circulatory system and muscle function. Some studies have reported that $\dot{V}O_2$max in trained people can remain unchanged after short-term detraining [12]. However, another study has shown that a higher $\dot{V}O_2$max training status results in a greater decrease in $\dot{V}O_2$max after short-term detraining [10]. The level of $\dot{V}O_2$max in highly trained athletes initially decreases progressively, but eventually, $\dot{V}O_2$max can be maintained at the control level after the long-term period [11], while those without an untrained background will completely lose their $\dot{V}O_2$max gain after a long-term period. These studies indicated that the training status of $\dot{V}O_2$max before detraining might affect the adverse effects of training cessation on $\dot{V}O_2$max between short- and long-term periods. Nevertheless, limited research makes the influence of $\dot{V}O_2$max training status on the relationship between the duration of training cessation and $\dot{V}O_2$max in trained athletes still controversial.

When exposed to the risk of detraining, athletes will face two forms of detraining: one is complete cessation of training (CDT), that is, in addition to daily physical activity, complete interruption of training; the other is partial cessation of training (PDT), that is, doing exercise at a certain intensity of each week during detraining [10, 13]. Compared with CDT, PDT seems to reduce or offset the adverse effects on physiological functions and morphology. A recent study has shown that the losses in training adaptations and exercise capacity that occur during periods of inactivity may at least be partially alleviated with a program of reduced training frequency and/or duration if intensity is maintained [14]. Barry et al. [12] reported that conducting a 40-minute training program at 80% HRmax intensity twice a week can maintain $\dot{V}O_2$max for the general population until 15 weeks. For the athlete group, research by Houmard and Mujika and Padilla [13, 15, 16] showed that the training frequency needs to be maintained above 80% of the original to decrease endurance performance. Although PDT is a training strategy to reduce the adverse effects of detraining, athletes have a different physiological response to training cessation in the short term or long term. Compared with CPT, the benefit and validation of PDT have not been evaluated by systematic review.

Changes in $\dot{V}O_2$max and endurance performance are related to age. Endurance performance can show the highest level only after 20 [17], and $\dot{V}O_2$max in adolescents is lower than that of adults because $\dot{V}O_2$max can reach the peak level after 20 years of age [18]. $\dot{V}O_2$max reflects muscles' ability to utilize oxygen. Lemmer et al. confirmed that the strength retention rate of young people is significantly greater than that of elderly people after 12-31 weeks of training cessation [18]. Although these studies may imply that age may play a moderating role in detraining $\dot{V}O_2$max, no studies have evaluated the effect of detraining $\dot{V}O_2$max between the adolescent population (<20) and adults (≥20).

Recently, the COVID-19 outbreak has exposed athletes to the risk of detraining, which dramatically raises the possibility of a decline in athletic performance, the disappearance of training adaptation, and the risk of injury. It is an emerging challenge for athletes and coaches to formulate appropriate detraining prevention strategies, which require us to comprehend the effect of detraining on $\dot{V}O_2$max. Nevertheless, the relevant assessment will be limited by different research methods. High-quality systematic reviews and meta-analyses can help us overcome these challenges, explain the bias and homogeneity of these studies, and provide a more accurate assessment of the effects. Therefore, the purpose of this study is to evaluate the impact of short- and long-term detraining on $\dot{V}O_2$max and assess the effects of age, training status, and detraining format on $\dot{V}O_2$max between the long- and short-term periods by a subgroup analysis.

2. Materials and Methods

This systematic review and meta-analysis followed the Cochrane Collaboration guidelines [19]. The systematic review strategy was conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines [20].

The literature search, identification, screening, and data extraction were conducted independently by two reviewers (TP and JZ). Disagreements between the reviewers were resolved by consensus or arbitration through a third reviewer (YkJ). Papers that were clearly not relevant were removed from the database list before abstracts were assessed using predetermined inclusion and exclusion criteria. The process of the study selection is shown in Figure 1.

2.1. Search Strategy. Electronic databases were searched in Web of Science, SPORTDiscus, PubMed, and Scopus. Searches were limited to papers published in English and from relevant publications prior to 31 March 2021. Keywords and synonyms were entered in various combinations (detraining OR deconditioning OR "training cessation" AND endurance* OR lactate* OR $\dot{V}O_2$max OR aerobic*).

2.2. Selection Criteria. Studies were eligible for inclusion if (a) the paper reported a specific detraining duration and gave a detailed value of $\dot{V}O_2$max before and after detraining, (b) the research subjects were athletes and were not limited by age, sex, event, or competitive level, and (c) articles were written in English.

Studies were excluded if (a) the paper reported relevant information unclearly or (b) the full text could not be obtained.

2.3. Extraction of Data. The characteristics of the 21 studies included in the meta-analysis can be found in Table 1. Two

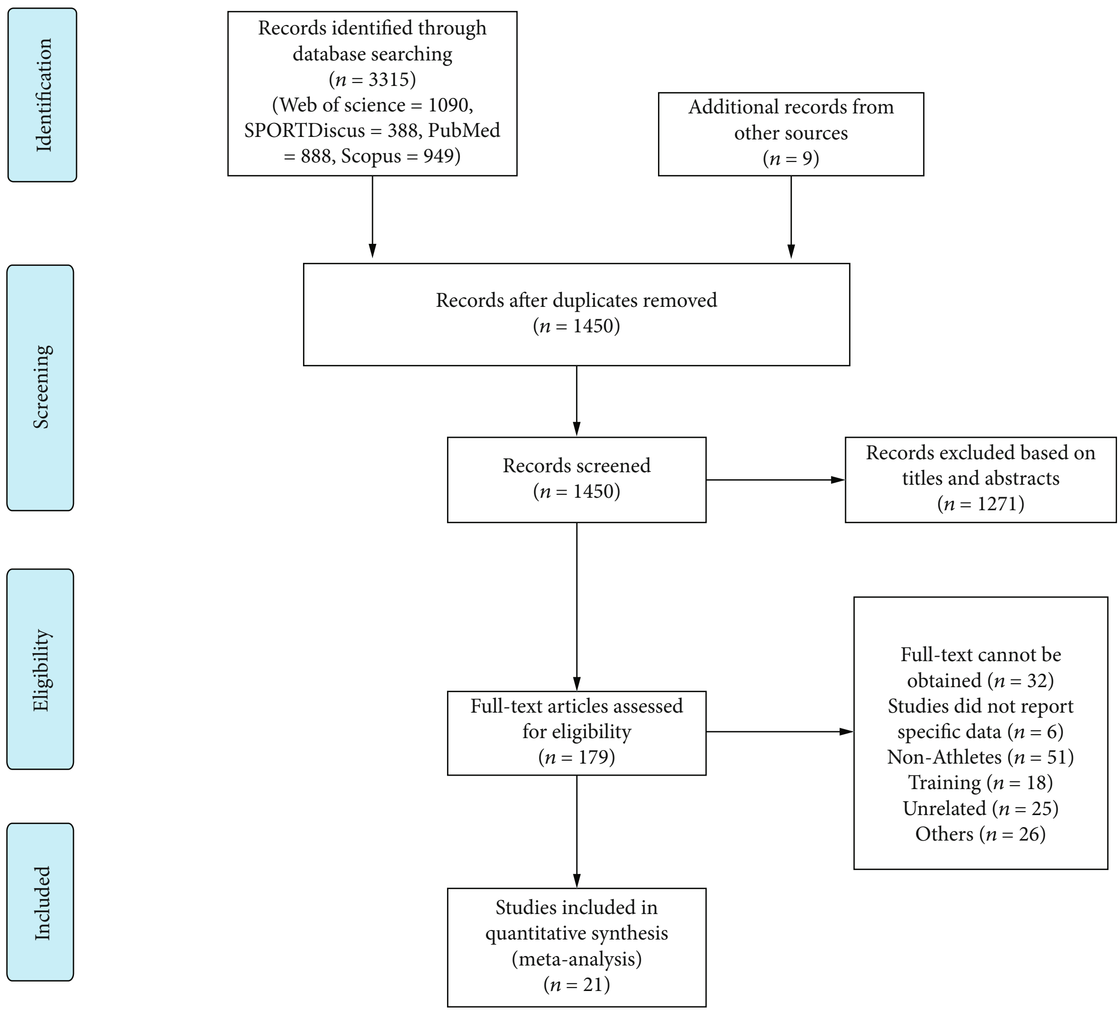

Figure 1: Flow chart of the study selection process.

independent reviewers (TP and JZ) read and coded each included study using the following moderators: authors and year of publication; training status (higher or lower); duration (days); sex (male, female, or mixed); age (<20 or ≥20); and detraining format (CDT or PDT).

2.4. Quality Assessment. Table 2 presents the summary of the STROBE statement checklist. The quality assessment was conducted independently by two reviewers (JZ and YkJ), and disagreements about outcomes were resolved by consensus or arbitration through a third reviewer (TP). The included articles were conducted using the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) checklist for cohort studies [21]. This checklist scores 22 items in the categories of title and abstract (item 1), introduction (items 2-3), methods (items 4-12), the results (items 13-17), discussion (items 18-21), and other information (item 22).

2.5. Synthesis of Results. Meta-analyses were conducted by the Meta package in R Studio (v1.41, Boston, USA). When comparing the duration of detraining effects on $\dot{V}O_2$max, the outcome data were divided into short-term (≤30 days) and long-term (>30 days) [10], and long-term periods of detraining were organized into 30-90 days and >90 days for further analysis in the long-term detraining period [11]. The standardized mean difference (SMD) for each study was calculated as Hedge's g effect size (ES) [22] to evaluate the magnitude of effects in different studies. Cohen's criteria [23] were used to interpret the magnitude of SMD: <0.5, small; 0.5 to 0.8, moderate; and >0.8, large. Data are presented as the mean and 95% CI. I^2 is used to quantify statistical heterogeneity as follows [24]: 0% to 40%: might not be important; 30% to 60%: may represent moderate heterogeneity*; 50% to 90%: may represent substantial heterogeneity*; and 75% to 100%: considerable heterogeneity* [25]. A fixed model was used for analysis; however, if statistical heterogeneity was shown ($I^2 < 40\%$), meta-analyses were performed using a random-effects model. Extended Egger's test [26] was used to assess the risk of bias across the studies.

3. Results

3.1. Study Identification and Selection. The search of databases and additional titles from other sources identified an

Table 1: Characteristics of the included studies.

Study	Training status	Duration (days)	Sample size (n)	Sex	Age	Cessation	Measures
Drinkwater et al. (1972) [27]	Lower	90	7	Female	<20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min) Lactate (mEq/liter)
Murase, Y et al. (1981) [28]	Higher	730	5	Male	<20	CDT	$\dot{V}O_2$max (ml/kg/min)
Coyle et al. (1984) [29]	Higher	12, 21, 56, 84	7	Mixed	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min)
Cullinane et al. (1986) [30]	Higher	10	15	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min)
Miyamura M et al. (1990) [31]	Lower	365, 455, 605, 730	5	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min)
Houmard et al. (1992) [32]	Higher	14	12	Mixed	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min)
Madsen et al. (1993) [33]	Higher	28	9	Male	≥20	CDT	$\dot{V}O_2$max (l/min) HRmax (beats/min)
LaForgia et al. (1999) [34]	Lower	21	8	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min)
Mochizuki et al. (1999) [35]	Higher	30	15	Mixed	<20	CDT	$\dot{V}O_2$max (ml/kg/min)
Doherty et al. (2003) [36]	Higher	15	7	Female	≥20	CDT	$\dot{V}O_2$max (ml/kg/min)
Petibois et al. (2003) [37]	Higher	35, 203, 364	10	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) Lactate (mEq/liter)
Gamelin et al. (2007) [38]	Lower	14,28, 56	14	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min)
Caldwell et al. (2009) [39]	Lower	90	13	Male	≥20	PDT	$\dot{V}O_2$max (ml/kg/min)
J Garciapallares (2000) [40]	Higher	35	7	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min) Lactate (mEq/liter)
Sotiropoulos et al. (2009) [41]	Higher	28	20,38	Male	≥20	PDT	$\dot{V}O_2$max (ml/kg/min)
Eastwood et al. (2012) [42]	Higher	30	9	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min)
Koundourakis et al. (2014) [43]	Higher	42	23,22	Male	≥20	PDT	$\dot{V}O_2$max (ml/kg/min)
Koundourakis et al. (2014) [44]	Higher	42	67	Male	≥20	PDT	$\dot{V}O_2$max (ml/kg/min)
Melchiorri et al. (2014) [45]	Lower	42	14	Male	<20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min)
Balague et al. (2016) [46]	Lower	21	8	Male	≥20	CDT	$\dot{V}O_2$max (ml/kg/min) HRmax (beats/min)
Melchiorri et al. (1999) [47]	Higher	56	15	Mixed	≥20	CDT	$\dot{V}O_2$max (ml/kg/min)

Duration (days): duration of detraining; higher: regular training will be conducted more than or equal to 5 times a week; lower: training will be less than 5 times a week; CDT: completely detraining; PDT: partly detraining.

initial 3315 titles. These studies were then exported to reference manager software (EndNoteX9, USA). Duplicates (1865 references) were subsequently removed either automatically or manually. The remaining 1450 articles were screened for their relevance based on titles and abstracts, resulting in the removal of an additional 1271 studies. The full texts of the remaining 179 articles were examined diligently; 158 articles were rejected as they did not satisfy the relevant criteria, including the following: full text could not be obtained ($n = 32$); studies did not report specific data ($n = 6$); nonathletes ($n = 51$); training ($n = 18$); unrelated ($n = 25$); and others ($n = 26$). Twenty-one articles were eligible for the systematic review and meta-analysis (Figure 1). The 21 studies included provided mean and standard deviation $\dot{V}O_2$max data for at least one main outcome.

3.2. Study Characteristics. The characteristics of the 21 studies included in the meta-analysis can be found in Table 1. Detraining periods varied between 10 and 730 days across the studies. Twenty-one studies were divided into short-term (<30 days), long-term (30-90 days), and ultralong-term (>90 days) studies.

Table 2 presents the summary of the STROBE statement checklist. From the 21 included studies in the meta-analysis, five studies were classified between 28 and 31, eleven between 32 and 35, and five between 36 and 39.

3.3. The Effects of Short-Term and Long-Term Training Cessation on $\dot{V}O_2$max. The forest plot shows the effects of short-term and long-term detraining on $\dot{V}O_2$max. Significant decreases in $\dot{V}O_2$max were identified after short-term

Table 2: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Overall
Murase et al.	1	2	2	2	1	1	2	2	0	0	2	0	1	2	2	2	0	2	1	2	1	0	28
Doherty et al.	2	2	2	2	1	1	2	2	1	0	2	2	2	2	2	2	0	2	2	2	2	1	36
Drinkwater et al.	1	2	2	2	1	1	2	1	0	0	2	2	1	2	2	2	0	2	1	2	1	0	29
Coyle et al.	1	2	2	2	1	1	2	2	1	0	2	2	1	2	2	2	2	2	1	2	1	2	35
Esatwood et al.	1	2	2	2	1	1	2	1	1	0	2	2	1	2	2	2	2	2	2	2	2	1	35
Houmard et al.	1	2	2	2	1	1	2	2	1	0	2	2	1	2	2	2	2	2	0	1	2	2	34
Yi-hung et al.	1	2	2	2	1	2	2	2	2	0	2	2	2	2	2	2	2	2	1	2	2	2	39
Petibois et al.	1	2	2	2	1	1	2	2	1	0	2	2	1	2	2	2	1	2	1	2	2	2	35
Balague et al.	1	2	2	2	1	1	2	2	1	0	2	2	2	1	2	2	2	2	2	2	2	2	37
Garcia et al.	2	2	2	2	1	1	2	2	0	0	2	2	2	2	2	2	0	2	2	2	1	1	34
LaForgia et al.	2	2	2	2	1	1	2	2	2	0	2	2	1	2	2	2	2	2	1	2	1	0	35
Mochizuki et al.	1	2	2	2	1	1	2	2	2	0	2	2	1	2	2	2	2	2	1	2	2	0	35
Androulakis et al.	1	2	2	2	1	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	1	39
TRAVLOS et al.	1	2	2	2	1	2	2	2	1	0	2	0	2	1	2	2	0	2	0	1	2	0	29
BRIAN et al.	1	2	2	2	1	1	2	1	2	0	2	0	2	1	2	2	0	2	2	2	2	1	32
Nikolaos et al.	1	2	2	2	1	2	2	2	2	0	2	0	2	1	2	2	0	2	2	2	2	1	34
Gamelin et al.	1	2	2	2	1	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	0	38
Eileen et al.	1	2	1	1	1	1	2	2	1	0	2	2	1	2	2	2	1	2	2	1	2	0	31
Melchiorri et al.	1	2	2	2	1	1	2	2	2	0	2	2	2	2	2	2	1	2	1	2	2	0	35
KLAVS et al.	1	2	2	2	1	1	2	2	1	0	2	1	1	2	2	2	2	2	1	2	1	1	33
Miharu et al.	1	2	2	2	1	1	2	2	1	0	2	0	1	2	2	1	2	0	1	2	2	1	30

1: title and abstract; 2: background/rationale; 3: objectives; 4: study design; 5: setting; 6: participants; 7: variables; 8: data sources/measurement; 9: bias; 10: study size; 11: quantitative variables; 12: statistical methods; 13: participants; 14: descriptive data; 15: outcome data; 16: main results; 17: other analyses; 18: key results; 19: limitations; 20: interpretation; 21: generalizability; and 22: funding (0: no information; 1: low; and 2: high).

training cessation (ES $= -0.62$ [95% CI -0.94; -0.31], $p < 0.01$; within-group $I^2 = 35.3\%$, Egger's test $= -1.22$, $p = 0.335$) and long-term training cessation (ES $= -1.42$ [95% CI -1.99; -0.84], $p < 0.01$; within-group $I^2 = 77\%$, Egger's test $= -3.369$, $p < 0.01$). The detrimental effect of detraining was found to be larger in long-term training cessation than in short-term training cessation ($Q = 6.5$, $p = 0.01$). The relative weight of each study in the short-term training cessation and long-term training cessation varied between 2.8% and 3.1% and between 1.6% and 3.6%, respectively (Figure 2).

3.4. Subgroup Analysis Results. The effect of training cessation on $\dot{V}O_2$max after long-term detraining is presented in Table 3. The subgroup analysis showed that there was no significant difference regarding $\dot{V}O_2$max change between 30-90 days detraining and larger than 90 days detraining ($Q = 0.54$, $p = 0.46$). However, the athletes with higher trained-state $\dot{V}O_2$max had a significant decline in $\dot{V}O_2$max after long-term detraining compared with the athletes with lower trained-state $\dot{V}O_2$max ($Q = 4.24$, $p = 0.03$). Younger (<20) trained individuals showed a greater reduction in $\dot{V}O_2$max after detraining than adult (≥20) trained individuals ($Q = 5.9$, $p = 0.05$). Compared with CDT, PDT had smaller effects of training cessation on $\dot{V}O_2$max ($Q = 6.23$, $p = 0.01$). The short-term detraining effect on $\dot{V}O_2$max is shown in Table 4. For short-term training cessation, the effect of detraining was not changed significantly between higher and lower trained-state $\dot{V}O_2$max athletes ($Q = 1.45$, $p = 0.22$), between ages ($Q = 0.27$, $p = 0.87$), or between CDT and PDT ($Q = 0.36$, $p = 0.55$).

4. Discussion

This systematic review and meta-analysis is aimed at assessing the magnitude of the effect on trained individuals' $\dot{V}O_2$max after short- and long-term training cessation. A detrimental impact on trained individuals' $\dot{V}O_2$max was observed during both short- and long-term training cessation, and a larger negative effect after the long-term period was identified compared with the short-term period. The subgroup analysis showed that the effects of age, training status, and detraining format led to the differing impacts of detraining on $\dot{V}O_2$max in the long-term period but did not change in the short-term period.

4.1. The Short-Term and Long-Term Effects on $\dot{V}O_2$max. The present study revealed that both short- and long-term detraining will cause a significant drop in the trained individual's $\dot{V}O_2$max, and the average $\dot{V}O_2$max decreased by 3.93% in the short-term period and by 9.43% in the long-term period. Training cessation or reduction causes insufficient or disappearance of training stimulation and leads to morphological and physiological functional changes, which may be the main factor for the harmful effects of long-term and short-term detraining on $\dot{V}O_2$max [10, 11]. It is

Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	SMD	95%−CI	Weight (common)	Weight (random)
Term = long term										
Drinkwater.el.al (1972)	7	40.40	1.0000	7	47.80	1.8000	−4.76	[−7.07; −2.45]	0.4%	1.6%
Murase, Y.el.al (1981)	5	61.44	3.4300	5	70.70	4.2800	−2.16	[−3.87; −0.44]	0.7%	2.1%
Coyle .el.al (1984)	7	53.20	2.1000	7	62.10	3.3000	−3.01	[−4.68; −1.34]	0.8%	2.2%
Coyle .el.al (1984)	7	50.80	1.9000	7	62.10	3.3000	−3.93	[−5.92; −1.93]	0.5%	1.8%
Miyamura M .el.al (1990)	5	60.30	4.7000	5	59.80	3.5000	0.11	[−1.13; 1.35]	1.4%	2.8%
Miyamura M .el.al (1990)	5	58.90	4.5000	5	59.80	3.5000	−0.20	[−1.45; 1.04]	1.4%	2.8%
Miyamura M .el.al (1990)	5	57.40	1.1000	5	59.80	3.5000	−0.84	[−2.16; 0.49]	1.2%	2.7%
Miyamura M .el.al (1990)	5	55.40	4.4000	5	59.80	3.5000	−1.00	[−2.36; 0.36]	1.2%	2.6%
Petibois .el.al (2003)	10	54.00	5.0000	10	63.00	5.0000	−1.72	[−2.78; −0.67]	1.9%	3.0%
Petibois .el.al (2003)	10	52.00	6.0000	10	63.00	5.0000	−1.91	[−3.00; −0.81]	1.8%	3.0%
Petibois .el.al (2003)	10	50.00	5.0000	10	63.00	5.0000	−2.49	[−3.71; −1.26]	1.4%	2.8%
Gamelin.el.al (2007)	10	53.10	2.9000	10	56.30	4.0000	−0.88	[−1.80; 0.05]	2.5%	3.2%
Caldwell .er.al(2009)	13	56.00	1.2000	13	58.00	1.9000	−1.22	[−2.07; −0.37]	2.9%	3.3%
Garcia−Pallares .el.al (2009)	7	61.30	2.7000	7	69.10	3.9000	−2.18	[−3.58; −0.77]	1.1%	2.5%
Koundourakis .er.al (2014)	23	57.67	2.5400	23	60.31	2.5200	−1.03	[−1.64; −0.41]	5.6%	3.6%
Koundourakis .er.al (2014)	22	58.30	3.8800	22	60.47	4.1300	−0.53	[−1.13; 0.07]	5.8%	3.7%
Nikolaos .el.al (2014)	67	58.89	3.4500	67	59.44	3.0700	−0.17	[−0.51; 0.17]	18.4%	3.9%
Melchiorri .el.al (2014)	14	49.46	6.5100	14	62.83	5.7700	−2.11	[−3.06; −1.16]	2.4%	3.2%
Yi−Hung .el.al (2016)	16	43.65	7.1000	16	45.03	8.2000	−0.18	[−0.87; 0.52]	4.4%	3.6%
Common effect model	248			248			**−0.83**	**[−1.02; −0.63]**	**55.6%**	−−
Random effects model							**−1.42**	**[−1.99; −0.84]**	−−	**54.5%**
Heterogeneity: $I^2 = 77\%$, $\tau^2 = 1.2059$, $p < 0.01$										
Term = short−term										
Coyle .el.al (1984)	7	57.70	2.6000	7	62.10	3.3000	−1.39	[−2.59; −0.18]	1.5%	2.8%
Coyle .el.al (1984)	7	57.90	3.1000	7	62.10	3.3000	−1.23	[−2.40; −0.05]	1.5%	2.9%
Cullinane. el.al (1986)	15	61.20	5.6000	15	61.30	6.2000	−0.02	[−0.73; 0.70]	4.1%	3.5%
Houmard .el.al (1992)	12	58.70	1.8000	12	61.60	2.0000	−1.47	[−2.39; −0.55]	2.5%	3.2%
Madsen .el.al (1993)	9	4.57	0.1000	9	4.54	0.0800	0.32	[−0.62; 1.25]	2.4%	3.2%
LaForgia .el.al (1999)	8	58.10	5.8000	8	59.30	5.8000	−0.20	[−1.18; 0.79]	2.2%	3.1%
Mochizuki .el.al (1999)	15	58.30	5.8000	15	63.10	5.5000	−0.83	[−1.58; −0.08]	3.8%	3.5%
Doherty.el.al (2003)	7	48.80	1.3000	7	49.80	1.1000	−0.78	[−1.88; 0.32]	1.8%	3.0%
Gamelin.el.al (2007)	10	54.30	4.1000	10	56.30	4.0000	−0.47	[−1.36; 0.42]	2.7%	3.3%
Gamelin.el.al (2007)	10	54.80	4.0000	10	56.30	4.0000	−0.36	[−1.24; 0.53]	2.7%	3.3%
Sotiropoulos .el.al (2009)	20	54.52	2.8000	20	58.08	2.6000	−1.29	[−1.98; −0.60]	4.5%	3.6%
Sotiropoulos .el.al (2009)	38	56.85	2.5200	38	57.66	2.5600	−0.32	[−0.77; 0.14]	10.3%	3.8%
Eastwood.el.al (2012)	9	59.90	5.0000	9	64.60	4.8000	−0.91	[−1.90; 0.07]	2.2%	3.1%
Balague .el.al (2016)	8	57.50	9.1000	8	60.10	9.7000	−0.26	[−1.25; 0.72]	2.2%	3.1%
Common effect model	175			175			**−0.58**	**[−0.80; −0.36]**	**44.4%**	−−
Random effects model							**−0.62**	**[−0.94; −0.31]**	−−	**45.5%**
Heterogeneity: $I^2 = 35\%$, $\tau^2 = 0.1736$, $p = 0.09$										
Common effect model	**423**			**423**			**−0.72**	**[−0.86; −0.57]**	**100.0%**	−−
Random effects model							**−1.04**	**[−1.40; −0.69]**	−−	**100.0%**
Prediction interval								**[−2.97; 0.88]**		
Heterogeneity: $I^2 = 68\%$, $\tau^2 = 0.8584$, $p < 0.01$										
Test for subgroup differences (common effect): $\chi^2_1 = 2.75$, df = 1 ($p = 0.10$)										
Test for subgroup differences (random effects): $\chi^2_1 = 6.52$, df = 1 ($p = 0.01$)										

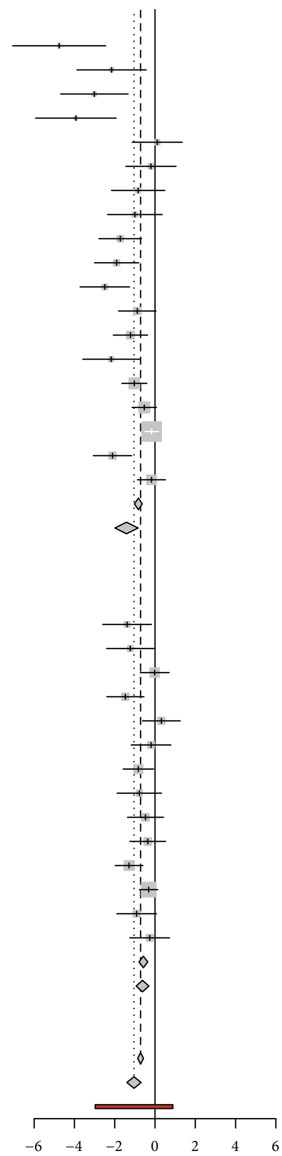

Figure 2: A forest plot of changes in $\dot{V}O_2$max for long-term and short-term training cessation. Mean and SD were reported on the plot and experimental group and control group means after detraining and before detraining, respectively. SMD: 95% confidence intervals (CI) and each study weight are shown on the right side. Gray boxes: each study's effect size, and gray diamonds: subgroup overall.

worth noting that there was no significant difference in the decline in $\dot{V}O_2$max between 30-90 days and longer than 90 days detraining in the subgroup analysis of long-term detraining. This result indicated that when training cessation occurred beyond a certain period, the harmful effects on $\dot{V}O_2$max no longer increased with the extension of the training suspension time. In fact, even without physical training, daily essential physical activity can also maintain normal physiological function and sustain cardiovascular fitness [48], which may help to explain the nonlinear relationship between the duration of training cessation and detraining effects in the long term. The research results show that there is a dose-effect relationship between the detraining duration and the detraining effect. When the training cessation exceeds a certain period (>90 days), the harmful effects caused by the training suspension will no longer continue to worsen. In practice, coaches and athletes must be aware of the difference between the short- and long-term harmful effects of $\dot{V}O_2$max to develop detraining prevention strategies. Long-term detraining needs to be avoided because long-term detraining has a greater detrimental effect on $\dot{V}O_2$max.

Table 3: Subgroup analysis of the long-term detraining effect on $\dot{V}O_2$max.

	k	SMD	95% CI	p	Q	I^2
Duration						
30-90 days	12	-1.6	-2.47; -0.74	<0.001	64.36	0.83
>90 days	7	-1.20	-2.13; -0.28	<0.001	14.66	0.59
Training state						
Higher	10	-1.91	-2.57; -1.25	<0.001	28.8	0.69
Lower	4	-0.85	-1.83; 0.12	<0.001	24.5	0.67
Age						
<20[b]	3	-2.81	-6.32; 0.69	<0.001	5.04	0.63
≥20	16	-1.20	-1.76; -0.64	<0.001	58.4	0.74
Format						
CDT	16	-1.69	-2.41; -0.96	<0.001	52.5	0.73
PDT	4	-0.65	-1.42; 0.11	<0.001	9.2	0.67

k: number of studies; SMD: <-0.5, small; 0.5 to 0.8, moderate; and >0.8, large; I^2: heterogeneity test.

Table 4: Subgroup analysis of the short-term detraining effect on $\dot{V}O_2$max.

	k	SMD	95% CI	p	Q	I^2
Training status						
Higher	7	-0.76	-1.10; -0.41	<0.001	9.32	0.37
Lower	7	-0.46	-0.75; -0.18	0.014	9.39	0.36
Age						
<20	1	-0.83	-1.57; -0.08	0.030	—	—
≥20	13	-0.61	-0.95; -0.26	<0.001	19.3	0.38
CDT	11	-0.54	-0.82; -0.26	<0.001	14.4	0.31
PDT	3	-0.65	-1.00; -0.30	0.01	5.76	0.65

k: number of studies; SMD: <-0.5, small; 0.5 to 0.8, moderate; and >0.8, large; I^2: heterogeneity test.

4.2. Detraining Format Differences in the Short-Term and Long-Term Effects on $\dot{V}O_2$max. An essential finding of this study is that exercise activities during long-term detraining can reduce the negative effect of detraining on $\dot{V}O_2$max compared with no exercise activities. However, there was no significant difference in the harmful effects of $\dot{V}O_2$max between CDT and PDT. The magnitude of detrimental impacts on $\dot{V}O_2$max in the PDT groups during the long-term period was small, and the percentage of decline in $\dot{V}O_2$max ranged from -4.38% to -0.93%; however, the negative effect was large, and $\dot{V}O_2$max decreased up to -11.12%. Recent research also supports the results of the current study and shows that performing jogging exercises with 50-60% $\dot{V}O_2$max intensity for 20-30 minutes each time 2-3 times a week during off-seasonal periods can offset the harmful effects of detraining on $\dot{V}O_2$max in football players [49, 50]. Many studies have shown that regular aerobic exercise can maintain a healthy level of $\dot{V}O_2$max in the human body [51–54]. This may be helpful to explain why athletes who exercise can delay the decline in oxygen uptake during long-term training cessation. It was unexpected that PDT had no buffering effect on the harmful impacts of $\dot{V}O_2$max during the short-term period. There were small negative effects on $\dot{V}O_2$max in both the CDT and PDT groups, and the decrease in $\dot{V}O_2$max levels of athletes ranged from -21.28% to 0.84% in the CDT group and varied from -4.38% to -0.93% in the PDT group. One possible explanation is that the intensity of the exercise is inappropriate. In the sample of this study, the exercise intensity during the short-term period was low, which may not play a role in maintaining $\dot{V}O_2$max. Recent studies have also shown that exercise intensity is the key for athletes to sustain $\dot{V}O_2$max [12]. It has been reported that high-intensity exercise 2 times a week can allow athletes to maintain $\dot{V}O_2$max for 15 weeks without decreasing [12]. In addition, there may be a minimum threshold for the reduction of $\dot{V}O_2$max during training cessation. In this study, a minimum of 2 weeks of training can cause a decrease in $\dot{V}O_2$max, and the research results suggest that athletes and coaches need to consider the different effects of long- and short-term detraining when making detraining prevention plans. During the long-term period, necessary exercise can offset some of the negative impacts on $\dot{V}O_2$max. In the short term, if there is not enough stimulation, there may be no difference in $\dot{V}O_2$max change between athletes who exercise and those who do not exercise at all.

4.3. The Training Status Difference in the Short-Term and Long-Term Effects on $\dot{V}$O2max. Long-term detraining has a more significant negative impact on athletes with higher levels of oxygen uptake training, which may be related to the training intensity that affects aerobic capacity. Studies have shown that training intensity rather than training frequency is crucial in maintaining $\dot{V}O_2$max levels [1, 55]. Athletes with higher training levels rely on higher training intensity to improve their physiological functions. Once training stimulation is lost, the training-induced gain for $\dot{V}O_2$max cannot be maintained. Long-term detraining makes the $\dot{V}O_2$max gain obtained by athletes through high-intensity training decrease or disappear more quickly. Athletes with a higher training status of $\dot{V}O_2$max have a more significant reduction in $\dot{V}O_2$max. The effect of short-term training cessation on $\dot{V}O_2$max was not affected by the level of $\dot{V}O_2$max, and there was no significant difference between the high-level and low-level groups. The current study is inconsistent with previous studies. Mujika and Padilla [10] summarize the results of some studies that show that athletes with higher oxygen uptake or aerobic power capacity have a more significant decrease in $\dot{V}O_2$max ranging between 4 and 14% after short-term training stops. The differences in the results of different studies may be due to the limitations of the previous research methods. Although previous studies have reported a greater percentage drop rate for athletes with a higher training status of $\dot{V}O_2$max, this is not enough to cause a significant difference in the magnitude of an adverse effect of training suspension on $\dot{V}O_2$max.

4.4. The Age Difference in the Short-Term and Long-Term Effects on $\dot{V}O_2$max. After long-term training cessation, the changes in athletes' $\dot{V}O_2$max were affected by age.

Compared with adult athletes, young athletes have a greater rate of decline in $\dot{V}O_2$max after long-term suspension. In general, $\dot{V}O_2$max can reach its peak level at the age of 20-30 and decreases by approximately 1% every year after 30 [56]. Therefore, a lack of long-term training stimulation may have a more significant impact on the cardiovascular function of young athletes than adult athletes. Only one study reported the effect of short-term training on $\dot{V}O_2$max for the adolescent population [35]. Therefore, it is impossible to examine the effect of age on $\dot{V}O_2$max during short-term training for subgroup analysis. Meanwhile, only three studies reported on $\dot{V}O_2$max for the junior [28, 35, 45] group, and the limited research samples required us to treat the study results with caution.

4.5. Research Limitations and Future Prospects. More research samples in this study come from male athletes or mixed genders, and only two studies are female athletes. The differences in the physiological structure of men and women [33] may affect the results of the study. It is necessary to examine the difference in $\dot{V}O_2$max change between sexes after short- and long-term detraining in subsequent studies. In addition, factors such as nutrition (i.e., sports supplementation), environment, or measurement methods may affect the changes in oxygen uptake during detraining [57–61]. Therefore, the effects of these factors on the change in oxygen uptake during training cessation will also be considered in a follow-up study. Studies have shown that certain exercises can buffer some harmful effects during long-term periods, but current research cannot identify the training intensity and training load of certain exercises. In future research, it is necessary to explore the minimum dose-effect relationship that can maintain $\dot{V}O_2$max after detraining. Previous studies have reported that $\dot{V}O_2$max is related to changes in physical fitness levels, and future studies should compare the differences in physical fitness. Finally, research bias may have affected the research results.

5. Conclusion

The detrimental effects of detraining on $\dot{V}O_2$max were identified in both short-term and long-term training cessation. A greater decline in $\dot{V}O_2$max after the long-term period was observed when it was compared to short-term training cessation; however, there was no significant difference regarding the reduction in $\dot{V}O_2$max found between 30-90 days detraining and more than 90 days detraining. Physical exercise during the period of detraining seems to weaken the detrimental effects on $\dot{V}O_2$max to some extent during long-term training cessation, but it does not work in short-term training cessation. Adolescent and individual trainers with a higher $\dot{V}O_2$max training status have a greater decline in oxygen uptake after long-term training cessation.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

The authors would like to thank the College of Sports Science and Physical Education at South China Normal University for providing assistance.

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Hindawi
BioMed Research International
Volume 2022, Article ID 7728973, 14 pages
https://doi.org/10.1155/2022/7728973

Review Article

Scientific Evidence of Traditional Chinese Exercise (Qigong) for Chronic Obstructive Pulmonary Disease: An Overview of Systematic Reviews and Meta-Analyses

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Received 24 May 2022; Revised 26 June 2022; Accepted 22 July 2022; Published 2 August 2022

Academic Editor: Bojan Masanovic

Background. As a traditional Chinese exercise, Qigong has potential benefits for the management of chronic obstructive pulmonary disease (COPD). This overview is aimed at assessing the existing evidence for the intervention of Qigong in COPD so as to provide scientific guidance for clinical decision-making. *Methods*. The systematic reviews (SRs)/meta-analyses (MAs) of Qigong for the treatment of COPD were obtained from 7 electronic databases with the search date set at April 5, 2022. Two researchers independently assessed the methodological quality, reporting quality, and evidence quality for the included SRs/MAs using the following tools: the Assessment of Multiple Systematic Reviews 2 (AMSTAR-2), the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA 2020), and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system. *Results*. A total of 13 SRs/MAs were included in this overview. All SRs/MAs assessed by AMSTAR-2 had more than one critical defect, so all SR/MAs were rated very low. Regarding the assessment of reporting quality, the results of PRISMA 2020 showed that none of the SRs/MAs were fully reported. In addition, the results of the GRADE assessment of the quality of evidence indicated that only 3 outcomes were rated as high quality across all SRs/MAs. *Conclusion*. Current evidence suggests that Qigong is effective and safe for the management of patients with COPD. However, the high risk of bias in the original clinical studies and the low quality of the SRs/MAs reduced the reliability of the results.

1. Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by persistent airflow limitation, recurrent respiratory symptoms, and extrapulmonary manifestations [1, 2]. According to the World Health Organization, COPD is projected to become the third leading cause of death globally by 2030 [3]. In addition, COPD-related mortality is expected to increase gradually due to increased environmental exposures (smoking, ambient particulate matter, etc.) and an aging population [4]. By 2060, more than 5.4 million people could die each year from COPD and related diseases [1]. Therefore, COPD is an important challenge for global public health. In addition to this, COPD also imposes a huge financial burden on individuals and society as it is associated with high disability rates [5].

Standardized rehabilitation can delay the acute exacerbation and progression of COPD patients and improve their quality of life. Therefore, pulmonary rehabilitation in COPD patients is valued by clinicians and researchers [6]. Exercise is seen as the key to pulmonary rehabilitation, with the main aim of improving aerobic capacity in COPD patients [7]. Qigong, as one of the four pillars of traditional Chinese medicine [8], was rejuvenated in the 1950s to include a series of techniques aimed at improving the physical, mental, emotional, and respiratory health. Since the 1980s and especially the 2000s, there has been considerable interest in Qigong as a potential therapeutic modality [9]. As a mind-body exercise, Qigong incorporates the elements of physical movement, spiritual guidance, and breath control [10, 11], and there are various forms of Qigong, such as Wuqinxi, Baduanjin, Yijinjing, and Liuzijue.

Over the past 5 years, a large number of systematic reviews (SRs)/meta-analyses (MAs) have been completed to assess the potential benefits of Qigong for the health management of patients with COPD. Based on evidence-based medicine theory, SRs/MAs are considered the gold standard for evaluating the benefits of clinical interventions [12]. The overview is a new approach to integrating multiple SR/MAs by evaluating their quality and outcomes, which can provide comprehensive evidence for clinical decision-making and identify critical gaps in evidence use. Therefore, the aim of our study was to critically evaluate the quality of SR/MA related to the effect of Qigong in patients with COPD through a systematic overview.

2. Materials and Methods

This research was conducted according to the Cochrane Handbook, and we followed the methods of Huang et al. [13] and Shi et al. [14].

2.1. Eligibility Criteria. Eligible studies meet the following criteria: (1) study of research: SRs/MAs of randomized controlled trials (RCTs) reported the efficacy or safety of Qigong in COPD; (2) inclusion of the population: patients identified as having COPD based on diagnostic criteria regardless of their age, nationality, or gender; (3) interventions: the intervention methods for the control group included conventional medicine (CM), routine activities (RA), breathing training (BT), and health education (HE); (4) outcomes: the forced expiratory volume in one second (FEV1), forced vital capacity (FVC), 6-min walking distance (6-MWD), the amount of air exhaled in the first second divided by all of the air exhaled during a maximal exhalation (FEV1/FVC), St George's respiratory questionnaire (SGRQ), COPD assessment test (CAT), percentage of the forced expiratory volume in one second (FEV1%), quality of life (QOL), the World Health Organization on quality of life brief scale (WHOQOL-BREF), medical research council dyspnea scale (MRC), and the percentage of predicted values of FEV1 (FEV1%pred).

Studies that met the following criteria were excluded: (1) network meta-analyses, SRs/MAs without quantitative synthesis, conference abstracts, reviews, editorials, case reports, and replication studies; (2) animal experiments; and (3) the control group used other traditional Chinese exercises.

2.2. Search Strategy. Two researchers (YX-W and HS-S) independently searched PubMed, Embase, Cochrane Library, CBM, CNKI, Wanfang database, and VIP database, and the search time ranged from the database establishment to April 5, 2022. A combined search strategy that incorporates keyword search and free-word search was adopted, where the keywords include "Qigong", "Chronic obstructive pulmonary disease", "meta-analysis", and "systematic review". The search strategy was adjusted to fit different databases. In addition, we manually searched for relevant references to ensure the completeness of the search. We also searched Web of Science and Scopus databases from the database establishment to June 22, 2022. The search strategy for PubMed is shown in Table 1.

2.3. Literature Screening and Data Extraction. Two independent researchers (PJ-L and HS-S) conducted the screening of the literature. The retrieved publications were imported into a literature management system (EndNote X9), and the initial screening was performed by firstly removing duplicates and subsequently reading the titles and abstracts. Finally, the full text was read to identify the final literature for inclusion. To ensure data integrity and consistency, the two researchers (K-Z and HS-S) used a predesigned data extraction table to extract the data. The extracts included first author, year of publication, country, number of RCTs (number of subjects), interventions, risk of bias assessment methods, interventions, and main findings.

2.4. Quality Evaluation for Inclusion in SRs/MAs. Two independent researchers (YX-W and HS-S) assessed the methodological quality, reporting quality, and evidence quality of the included SRs/MAs. Any disagreements were referred to a third investigator (M-W) for consultation.

2.4.1. Methodological Quality Evaluation. The methodological quality of the included SRs/MAs was assessed using the Assessment of Multiple Systematic Reviews 2 (AMSTAR-2) [15]. The tool contains seven key items (2, 4, 7, 9, 11, 13, and 15). Each item was categorized as "no," "partially yes," or "yes" depending on their compliance with the criteria. The overall methodological quality was classified into four levels: high, medium, low, or very low.

2.4.2. Report Quality Evaluation. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA 2020) [16] was used to assess the quality of the report, and it covers 27 items. Each item can be assessed as "yes," "partially yes," or "no," with a ratio based on the assessment of each item.

2.4.3. Evidence Quality Evaluation. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) [17] system was applied to assess the quality of evidence for inclusion in the SR/MA outcome indicators. Evidence quality may be downgraded due to the following 5 criteria: risk of bias, inconsistency, indirectness, imprecision, and publication bias. The quality of evidence was categorized as high, moderate, low, and very low.

3. Results

3.1. Literature Selection. Nine electronic database searches identified 193 publications, 119 of which were excluded after removing duplicates. Afterwards, 13 publications were excluded by screening the titles and abstracts. Then, further screening was performed by reading the full text, and three papers [18–20] were excluded in this step due to their failure to meet the intervention criteria. Ultimately, a total of 13 papers [21–33] were

Table 1: Search strategy for the PubMed database.

Query	Search term
#1	“Qigong” [Mesh]
#2	“Qi-gong” OR “Qi gong” OR “Chi chung” OR “Chi gong” OR “Chi Kung” OR “Qi Kung” OR “Jhi gong” OR “Chi gung” OR “Qi chung” OR “Ch’i kung” OR “Kung ch’i” OR Baduanjin OR Yijinjing OR Wuqinxi OR “Wu qin xi” OR “Shi’erduanjin” OR “changing tendon exercise” OR “five mimic-animal exercises” OR “six-character formula” OR “five elements balance work” OR “Longmen five elements skill” OR “Mawangdui” OR “Qigong”
#3	#1 OR #2
#4	Pulmonary Disease, Chronic Obstructive [Mesh]
#5	“Chronic Obstructive Lung Disease” OR “Chronic Obstructive Pulmonary Diseases” OR “COAD” OR “COPD” OR “Chronic Obstructive Airway Disease” OR “Chronic Obstructive Pulmonary Disease” OR “Airflow Obstruction, Chronic” OR “Airflow Obstructions, Chronic” OR “Chronic Airflow Obstructions” OR “Chronic Airflow Obstruction”
#6	#4 OR #5
#7	Meta-analysis as topic [mesh]
#8	“Systematic review” OR “meta-analysis” OR “meta analysis” OR “meta-analyses” OR “Review, Systematic” OR “Systematic reviews”
#9	#7 OR #8
#10	#3 AND #6 AND #9

included. The flow chart of literature screening in this study is shown in Figure 1.

3.2. Characteristics of the SRs/MAs. The characteristics of the 13 SRs/MAs used for qualitative analysis in this overview are summarized in Table 2. All SRs/MAs were published between 2015 and 2021, with 12 (12/13, 92.3%) [21–28, 30–33] of them published within the last 5 years. In the original study of SRs/MAs included in this overview, the first RCT of Qigong intervention in COPD was published in 2008 by Chen et. al [34]. All included SRs/MAs were published by Chinese scholars, five [21, 22, 27, 28, 31] of which were written in English and eight [23–26, 29, 30, 32, 33] in Chinese. The number of RCTs included per SR/MA ranged from 8 to 30, and the participants in these RCTs ranged from 534 to 3,045. In terms of intervention modality, the control group was treated by CM, RA, BT, and HE, while the experimental group was treated by various types of Qigong or Qigong in combination with the treatments received by the control group. The various types of Qigong included Baduanjin, Liuzijue, Wuqinxi, and Yijinjing. Twelve [21, 23–33] SRs/MAs used the Cochrane criteria for risk of bias assessment of included RCTs, and the remaining 1 SR/MA [22] used the physical therapy evidence database scale. In addition to this, all SRs/MAs were subjected to meta-analysis and all reported positive results.

3.3. Quality Assessment

3.3.1. Methodological Quality Assessment. AMSTAR-2 was used to evaluate the methodological quality of the SRs/MAs included in this study, the details of which are given in Table 3. The methodological quality of all SRs/MAs was very low due to multiple deficiencies in critical and noncritical items. The deficiencies in the inclusion of SRs/MAs assessed by AMSTAR-2 were as follows: Item 2 (only 2 [27, 28] SRs/MAs have registered study protocols), Item 7 (none of the SR/MA provided a list of excluded articles), Item 10 (none of the SR/MAs provided a list of funding for RCTs), and Item 15 [21–23, 25, 26, 28] (only 6 SRs/MAs completed the publication bias assessment).

3.3.2. Report Quality Assessment. Detailed information on the quality of the report is presented in Table 4. Although the titles, abstracts, introductions, and discussions of the SRs/MAs included in this overview were reported in their entirety, some reporting deficiencies were still identified in other sections. In Materials and Methods, Item 7 (search strategy), Item 13(e) and (f) (synthesis methods), Item 14 (reporting bias assessment), and Item 15 (certainty assessment) have less than 50% response rate. In the results section, less than half of Item 20(d) (results of syntheses), Item 21 (reporting biases), and Item 22 (certainty of evidence) were reported. Only 2 [27, 28] (2/13, 15.38%) SRs/MAs provided information on the registration of study protocols, which made the quality assessment of Item 24 (registration and protocol) reporting unsatisfactory. In addition to this, only 5 [21, 22, 27, 28, 31] (5/13, 38.46%) SRs/MAs reported conflicts of interest, which rendered Item 26 (competing interests) reporting insufficient.

3.3.3. Evidence Quality Assessment. The 13 SRs/MAs included in this overview contain 73 outcomes. Results of the quality of evidence assessment showed that 3 items were rated as high quality, 17 items were rated as moderate quality, 23 items were rated as low quality, and the remaining 30 items were rated as very low quality. Among the downgrading factors, publication bias ($n = 58$) was the most common downgrading factor, followed by inconsistency ($n = 52$), risk of bias ($n = 25$), imprecision ($n = 21$), and indirectness ($n = 0$). Detailed information on the quality of the evidence is presented in Table 5.

3.4. Summary of the Outcomes of the Qigong Intervention COPD. We presented a summary and narrative description of the outcome indicators quantitatively assessed by the SRs/MAs in this overview. Complete information is presented in Table 6.

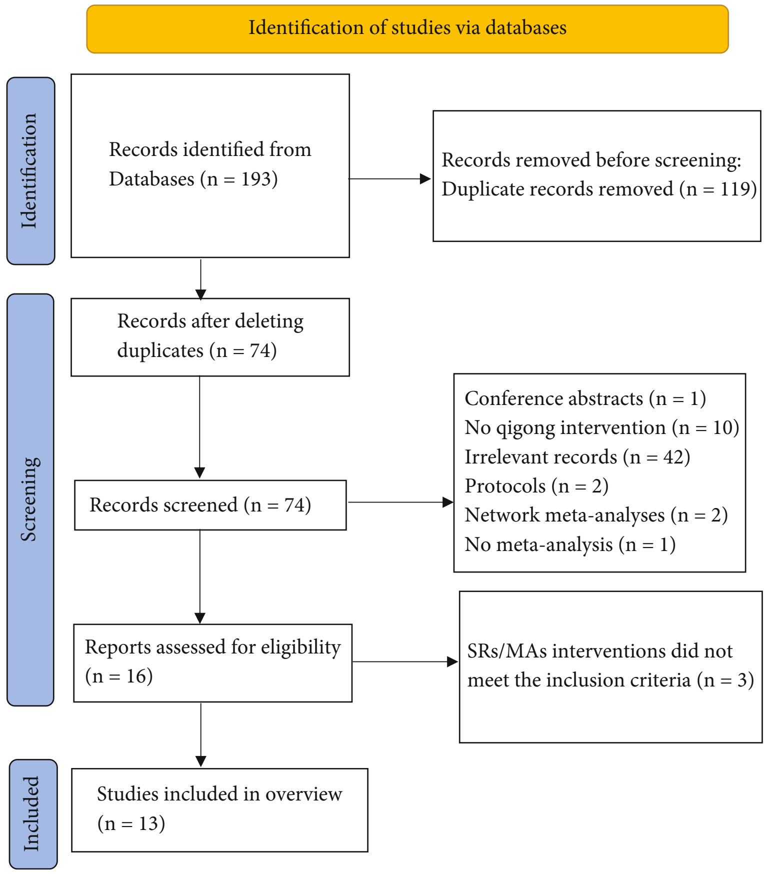

Figure 1: The flowchart of the screening process.

3.4.1. Effect of Qigong on Exercise Endurance. Twelve SRs/MAs [21, 22, 24–33] reported the effect of Qigong on 6-WMD, and the results indicated that Qigong could significantly improve 6-WMD in COPD patients.

3.4.2. Effect of Qigong on Lung Function. Twelve SRs/MAs [21–31, 33] reported that Qigong could significantly improve FEV1 in COPD patients. Eleven SRs/MAs [22–31, 33] reported the effect of Qigong on FEV1%, of which 10 SRs/MAs [22–31] showed that Qigong could significantly improve FEV1% in COPD patients. Ten SRs/MAs [21–28, 31, 33] reported the effect of Qigong on FEV1/FVC, and the results of 9 SRs/MAs [21–28, 31, 33] indicated that Qigong could significantly improve FEV1/FVC in COPD patients. Six SRs/MAs [21–26] reported that Qigong could significantly improve FVC in COPD patients. In addition, 3 SRs/MAs [25, 27, 33] reported that Qigong could significantly improve FEV1/pred% in COPD patients.

3.4.3. Effect of Qigong on Dyspnea. Three SRs/MAs [25, 28, 30] reported that Qigong could significantly improve MRC in COPD patients.

3.4.4. Effect of Qigong on Quality of Life. Seven SRs/MAs [21, 23, 26, 27, 30–32] reported the effect of Qigong on CAT, and the results of 6 SRs/MAs [21, 23, 27, 30–32] indicated that Qigong could significantly reduce CAT in COPD patients. Three SRs/MAs [21, 26, 27] reported that Qigong could significantly reduce SGRQ in COPD patients. One SR/MA [26] reported that Qigong could significantly improve WHOQOL-BREF in COPD patients. In addition, two SRs/MAs [22, 28] reported that Qigong could significantly improve the quality of life of COPD patients by comprehensively evaluating the effect of Qigong on CAT and SGRQ.

3.5. Adverse Events. None of the SRs/MAs quantified the adverse events of Qigong in patients with COPD, and two SRs/MAs [27, 30] descriptively set forth the safety of Qigong in patients with COPD.

4. Discussion

COPD rehabilitation is a key approach to COPD treatment recommended by current guidelines, and the recommended approach to rehabilitation includes physical exercise [35, 36]. As an important supplement to the physical exercise of COPD patients, Qigong can achieve the purpose of unity of body and mind through specific movements, breathing techniques, and meditation, thereby regulating the patient's energy (qi) and benefiting the patient's physical, mental, and spiritual health [37]. Although the number of published SRs/MAs on the Qigong treatment for COPD is on the increase, no published overview has so far put them together and assessed their quality. Therefore, an overview of this topic is necessary.

Table 2: Characteristics of the included SRs/MAs.

Citation	Trials (subjects)	Intervention group	Control group	Quality assessment	Main results
Cao et al. [21]	31 (3,045)	Baduanjin+control group	CM, RA, BT	Cochrane criteria	Baduanjin exercise can improve lung function, exercise capacity, and quality of life in COPD patients.
Liu et al. [22]	20 (1,975)	Baduanjin+control group	CM, RA, BT	Physical therapy evidence database scale	Baduanjin exercise as a complementary therapy can improve exercise capacity, lung function, and quality of life in COPD patients.
Chen et al. [23]	12 (1,245)	Baduanjin+control group	CM, RA, BT	Cochrane criteria	Baduanjin exercise can improve lung function, improve exercise tolerance, and improve the quality of life of patients with COPD.
Han et al. [24]	9 (960)	Baduanjin+control group	CM, RA, BT	Cochrane criteria	Baduanjin exercise can improve lung function and exercise endurance in COPD patients.
Li et al. [25]	12 (1,179)	Baduanjin+control group	CM, RA, BT	Cochrane criteria	Baduanjin exercise can improve lung function and exercise endurance in COPD patients.
Xie et al. [26]	25 (2,058)	Baduanjin+control group	CM, RA, BT, HE	Cochrane criteria	Baduanjin exercise as a complementary therapy can improve exercise capacity, lung function, and quality of life in COPD patients.
Xiao et al. [27]	14 (920)	Liuzijue+control group	CM, RA, BT	Cochrane criteria	Liuzijue exercise can effectively improve dyspnea, exercise capacity, lung function, and quality of life in COPD patients.
Gao et al. [28]	16 (1,039)	Liuzijue+control group	CM, RA, BT	Cochrane criteria	Liuzijue exercise can effectively improve dyspnea, exercise capacity, lung function, and quality of life in COPD patients.
Liu et al. [29]	10 (578)	Liuzijue+control group	CM, RA, BT	Cochrane criteria	Liuzijue can improve exercise tolerance, respiratory function, and quality of life in patients with stable COPD.
Zhang et al. [30]	18 (1,036)	Liuzijue+control group	CM, RA, BT	Cochrane criteria	Liuzijue can improve exercise tolerance, respiratory function, and quality of life in patients with stable COPD.
Tong et al. [31]	10 (993)	Liuzijue, Baduanjin, Yijinjing, Wuqinxi +control group	CM, RA, BT	Cochrane criteria	Qigong exercise improved lung function, exercise capacity, and patients' quality of life within 6 months.
Li et al. [32]	20 (1,824)	Liuzijue, Baduanjin, Yijinjing+control group	CM, RA, BT	Cochrane criteria	Qigong exercise combined with basic therapy can improve lung function, exercise tolerance, and quality of life in stable COPD patients compared with basic therapy.
Yuan et al. [33]	8 (578)	Wuqinxi, Wuqinxi +control group	CM, RA, BT	Cochrane criteria	Wuqinxi exercise can improve lung function in COPD patients.

Note: CM: conventional medicine; RA: routine activities; BT: breathing training; HE: health education.

Table 3: Result of the AMSTAR-2 assessments.

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Overall quality
Cao et al. [21]	Y	PY	Y	PY	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	VL
Liu et al. [22]	Y	PY	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	VL
Chen et al. [23]	Y	PY	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	VL
Han et al. [24]	Y	PY	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	N	Y	VL
Li et al. [25]	Y	PY	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	VL
Xie et al. [26]	Y	PY	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	VL
Xiao et al., 2020 [27]	Y	Y	Y	PY	Y	Y	N	Y	Y	N	Y	Y	Y	N	N	Y	VL
Gao et al. [28]	Y	Y	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	VL
Liu et al. [29]	Y	PY	Y	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	N	VL
Zhang et al. [30]	Y	PY	Y	PY	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	VL
Tong et al. [31]	Y	PY	Y	PY	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	VL
Li et al. [32]	Y	PY	Y	PY	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	VL
Yuan et al. [33]	Y	PY	Y	PY	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	N	VL

Note: Y: yes; PY: partial yes; N: no; VL: very low; H: high; key areas are marked in red.

This overview is the first evaluation of Qigong for COPD-related SRs/MAs using AMSTAR-2, PRISMA 2020, and GRADE. More than 90% (12/13, 92.3%) of these SRs/MAs were published in the last five years, indicating the growing interest in Qigong for COPD. However, the quality of the included SRs/MAs was not satisfactory.

4.1. Questions about the Quality of the Current Evidence and Recommendations. Based on the details of the AMSTAR-2 assessment, the major factors for the low methodological quality of the included SRs/MAs were as follows: Item 2 (protocol registration, 2/13, 15.38%), Item 7 (exclusion list, 0/13, 0%), Item 10 (funding sources, 0/13, 0%), and Item 15 (publication bias assessment, 6/13, 46.15%). Study protocol registration is important when researchers identify topics for SRs/MAs, which helps improve processing transparency and minimizes selective reporting bias [38]. A list of excluded literature was not provided for all included SR/MAs, which may affect the reproducibility of results and undermine the transparency of the study, making it difficult to ensure the reliability of the results. None of the SRs/MAs provided funding resources, which may increase bias in the reporting of clinical trials, as the results of commercially funded studies may be biased toward the institution in question. In addition, only 6 SRs/MAs were assessed for publication bias, which may lead to less confidence in the results of SRs/MAs.

Regarding reporting quality, the results of PRISMA 2020 showed that, like AMSTAR-2, the study protocol, RCTs funding, and publication bias were not fully reported. In addition, the lack of a complete search strategy, sensitivity analysis, and certainty of evidence assessment are also important reasons for the low quality of the report. Only 2 (2/13, 15.38%) SRs/MAs provided a complete search strategy for all electronic databases, which makes the studies nonreproducible and may also lead to publication bias. Only 5 (5/13, 38.46%) SRs/MAs were subjected to sensitivity analysis, and the absence of sensitivity analysis was detrimental to the stability of the judgmental effect size assessment, resulting in a decrease in the credibility of the results. In addition, none of the SR/MAs reported certainty of evidence, which is significant for our study.

For the assessment of evidence quality, only 3 of the 73 outcomes assessed were rated as high quality. A closer analysis revealed that publication bias (58/73, 79.45%) and inconsistency (30/73, 71.23%) were the main factors contributing to the downgrading of the quality of the evidence. Publication bias arises due to insufficient assessment of publication bias and an insufficient number of RCTs with relevant outcomes. Further analysis revealed a high degree of heterogeneity in many of the results, likely due to clinical and methodological differences in the included RCTs. Since the included RCTs include COPD patients of different ages, genders, and clinical stages, there is no uniform standard regarding the intervention time, frequency of intervention, and movements of Qigong. Due to the adoption of different measurement tools and methods, the same outcome measures may also differ in different studies, which is also a potential cause of heterogeneity.

Through a narrative overview of the outcome indicators of COPD treated with Qigong, we found that Qigong is effective and safe for COPD patients. Qigong has significant effects on improving lung function, exercise tolerance, dyspnea, and quality of life in COPD patients. However, caution is still required when recommending Qigong for COPD treatment, as the included SRs/MAs are of low quality and may not serve as a scientific basis for clinical practice by clinicians.

Our study suggests that Qigong may be a promising complementary therapy for COPD, but due to the overall low quality of the included evidence, the following is strongly recommended for the carrying out of SRs/MAs and RCTs in the future. For TCM-related SRs/MAs, registration on international platforms (e.g., Cochrane Library, PROSPERO, INPLASY, and JBI) and/or early publication of protocols are highly recommended. When conducting SRs/MAs, researchers should provide a complete list of search strategies for each electronic database, a list of excluded literatures, and the source of funding for the RCT to increase the transparency and reduce

Table 4: Results of the PRISMA checklist.

Section/topic		Items	Cao et al. [21]	Liu et al. [22]	Chen et al. [23]	Han et al. [24]	Li et al. [25]	Xie et al. [26]	Xiao et al. [27]	Gao et al. [28]	Liu et al. [29]	Zhang et al. [30]	Tong et al. [31]	Li et al. [32]	Yuan et al. [33]	Number of yes or partially yes (%)
Title	Title	Item 1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Abstract	Abstract	Item 2	PY	PY	PY	PY	PY	PY	PY	PY	PY	PY	PY	PY	PY	100%
Introduction	Rationale	Item 3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Objectives	Item 4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Methods	Eligibility criteria	Item 5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Information sources	Item 6	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Search strategy	Item 7	Y	N	N	N	N	N	N	Y	N	N	Y	N	N	23.08%
	Selection process	Item 8	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	92.31%
	Data collection process	Item 9	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Data items	Item 10(a)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 10(b)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Study risk of bias assessment	Item 11	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Effect measures	Item 12	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Synthesis methods	Item 13(a)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 13(b)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 13(c)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 13(d)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 13(e)	N	N	Y	N	N	Y	N	Y	Y	N	N	Y	Y	46.15%
		Item 13(f)	N	N	N	N	N	N	N	Y	N	N	N	Y	Y	23.08%
	Reporting bias assessment	Item 14	Y	Y	Y	N	Y	N	N	Y	N	N	Y	N	N	46.15%
	Certainty assessment	Item 15	N	N	N	N	N	N	N	N	N	N	N	N	N	0%
Results	Study selection	Item 16(a)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 16(b)	N	N	N	N	N	N	N	N	N	N	Y	N	N	7.69%
	Study characteristics	Item 17	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Risk of bias in studies	Item 18	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Results of individual studies	Item 19(a)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 19(b)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Results of syntheses	Item 20(a)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 20(b)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 20(c)	N	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	69.23%

Table 4: Continued.

Section/topic		Items	Cao et al. [21]	Liu et al. [22]	Chen et al. [23]	Han et al. [24]	Li et al. [25]	Xie et al. [26]	Xiao et al. [27]	Gao et al. [28]	Liu et al. [29]	Zhang et al. [30]	Tong et al. [31]	Li et al. [32]	Yuan et al. [33]	Number of yes or partially yes (%)
		Item 20(d)	N	N	Y	N	Y	Y	N	Y	N	Y	N	N	N	38.46%
	Reporting biases	Item 21	Y	Y	Y	N	Y	Y	N	Y	N	N	N	N	N	46.15%
	Certainty of evidence	Item 22	N	N	N	N	N	N	N	N	N	N	N	N	N	0%
Discussion	Discussion	Item 23(a)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 23(b)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 23(c)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
		Item 23(d)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Other information	Registration and protocol	Item 24(a)	N	N	N	N	N	N	Y	Y	N	N	N	N	N	15.38%
		Item 24(b)	N	N	N	N	N	N	Y	Y	N	N	N	N	N	15.38%
		Item 24(c)	N	N	N	N	N	N	N	N	N	N	N	N	N	0%
	Support	Item 25	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	N	69.23%
	Competing interests	Item 26	Y	Y	N	N	N	N	Y	Y	N	N	Y	N	N	38.46%
	Availability of data, code, and other materials	Item 27	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%

Note: Y: yes; N: no; PY: partially yes.

Table 5: Results of evidence quality.

Citation	Outcomes	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Quality
Cao et al. [21]	FEV1	-1①	-1②	0	0	-1④	Very low
	FVC	-1①	-1②	0	0	-1④	Very low
	FEV1/FVC	-1①	-1②	0	0	-1④	Very low
	6-MWD	-1①	-1②	0	0	-1④	Very low
	SGRQ	-1①	-1②	0	0	-1④	Very low
	CAT	-1①	-1②	0	0	-1④	Very low
Liu et al. [22]	6-MWD	0	-1②	0	0	0	Moderate
	FEV1	0	-1②	0	0	0	Moderate
	FEV1%	0	-1②	0	0	0	Moderate
	FVC	0	0	0	0	0	High
	FEV1/FVC	0	-1②	0	0	0	Moderate
	Quality of life	0	-1②	0	0	0	Moderate
Chen et al. [23]	FEV1	0	0	0	0	-1④	Moderate
	FEV1%	0	0	0	0	-1④	Moderate
	FVC	0	0	0	0	-1④	Moderate
	FEV1/FVC	0	-1②	0	0	-1④	Low
	CAT	0	-1②	0	0	-1④	Low
Han et al. [24]	6-MWD	0	0	0	-1③	-1④	Low
	FEV1	0	-1②	0	0	-1④	Low
	FEV1%	0	0	0	0	-1④	Moderate
	FVC	0	0	0	-1③	-1④	Low
	FEV1/FVC	0	-1②	0	-1③	-1④	Very low
Li et al. [25]	FEV1/pred%	0	-1②	0	0	-1④	Low
	FEV1	0	-1②	0	-1③	0	Low
	FEV1%	0	-1②	0	0	0	Moderate
	FVC	0	0	0	-1③	0	Moderate
	6-MWD	0	-1②	0	0	0	Very low
Xie et al. [26]	6-MWD	-1①	-1②	0	0	-1④	Very low
	FEV1	-1①	-1②	0	0	-1④	Very low
	FEV1%	-1①	-1②	0	0	0	Low
	FVC	-1①	-1②	0	0	-1④	Very low
	FEV1/FVC	-1①	-1②	0	0	-1④	Very low
	CAT	0	-1②	0	-1③	-1④	Very low
	SGRQ	-1①	-1②	0	0	-1④	Very low
	WHOQOL-BREF	0	-1②	0	0	-1④	Low
Xiao et al. [27]	MRC	0	-1②	0	-1③	-1④	Very low
	6-MWD	0	0	0	-1③	-1④	Low
	FEV1	0	-1②	0	0	-1④	Low
	FEV1/pred%	-1①	-1②	0	0	-1④	Very low
	FEV1/FVC	0	-1②	0	0	-1④	Low
	CAT	0	-1②	0	0	-1④	Low
	SGRQ	0	-1②	0	-1③	-1④	Very low
Gao et al. [28]	MRC	0	0	0	0	-1④	Moderate
	6-MWD	0	0	0	0	0	High
	FEV1	0	0	0	0	0	High
	FEV1%	0	-1②	0	0	0	Moderate

Table 5: Continued.

Citation	Outcomes	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Quality
	FEV1/FVC	0	-1②	0	0	0	Moderate
	Quality of life	0	-1②	0	0	-1④	Low
Liu et al. [29]	6-MWD	-1①	0	0	-1③	-1④	Very low
	FEV1	-1①	0	0	-1③	-1④	Very low
	FEV1%	-1①	0	0	-1③	-1④	Very low
Zhang et al. [30]	MRC	-1①	0	0	-1③	-1④	Very low
	6-MWD	0	-1②	0	0	-1④	Low
	FEV1	-1①	-1②	0	-1③	-1④	Very low
	FEV1%	-1①	-1②	0	0	-1④	Very low
	CAT	-1①	0	0	-1③	-1④	Very low
Tong et al. [31]	6-MWD	0	-1②	0	0	-1④	Low
	FEV1	0	-1②	0	0	-1④	Low
	FEV1/FVC	0	0	0	0	-1④	Moderate
	FEV1%	0	-1②	0	0	-1④	Low
	CAT	0	-1②	0	-1③	-1④	Very low
Li et al. [32]	FEV1% (3 months)	0	0	0	0	-1④	Moderate
	FEV1% (6 months)	0	-1②	0	0	-1④	Low
	FEV1/FVC (3 months)	0	-1②	0	0	-1④	Low
	FEV1/FVC (6 months)	0	-1②	0	0	-1④	Low
	CAT	0	0	0	-1③	-1④	Low
	6-MWD (3 months)	0	0	0	0	-1④	Moderate
	6-MWD (6 months)	0	-1②	0	0	-1④	Low
Yuan et al. [33]	FEV1	-1①	-1②	0	-1③	-1④	Very low
	FEV1%	-1①	-1②	0	-1③	-1④	Very low
	FEV1/FVC	-1①	-1②	0	0	-1④	Very low
	FEV1/pred%	-1①	-1②	0	-1③	-1④	Very low
	6-MWD	-1①	-1②	0	-1③	-1④	Very low

Note: ① the included studies have a large bias in methodology such as randomization, allocation concealment, and blinding. ② The confidence interval overlaps less or the I^2 value of the combined results was larger. ③ The sample size from the included studies does not meet the optimal sample size or the 95% confidence interval crosses the invalid line. ④ The funnel chart is asymmetry; FEV1: the forced expiratory volume in one second; FVC: forced vital capacity; 6-MWD: 6 min walking distance; FEV1/FVC: the amount of air exhaled in the first second divided by all of the air exhaled during a maximal exhalation; SGRQ: St George's respiratory questionnaire; CAT: COPD assessment test; FEV1%: percentage of the forced expiratory volume in one second; QOL: quality of life; WHOQOL-BREF: the World Health Organization on quality of life brief scale; MRC: medical research council dyspnea scale; FEV1%pred: the percentage of predicted values of FEV1.

the publication bias of the article. To improve the reliability of the results, publication bias assessment and sensitivity analysis should be performed.

4.2. Implications for Future Practice and Research. The improvement in exercise capacity, lung function, and quality of life in COPD patients may be related to the exercise pattern of Qigong, which, as a light to moderate aerobic exercise, is well suited for COPD patients with low exercise tolerance [39]. Qigong includes musculoskeletal stretching, breathing regulation, and mental coordination. These motor components may be the key to enhancing lung function and diaphragm capacity in COPD patients. In addition, Qigong also involves mental focus and relaxation, which can increase the sense of well-being in COPD patients, thus promoting the patients' mental health and increasing compliance with Qigong exercises.

A prerequisite for high-quality SRs/MAs is that the original studies included are of high quality. Clinical researchers should improve the top-level design of clinical trials through comprehensive evaluation and sophisticated analysis. Notably, Consolidated Standards of Reporting Trials (CONSORT) should be used to improve the quality of evidence from RCTs [40]. Careful design, rigorous implementation, and complete reporting of RCTs are considered gold standards for avoiding the research error [41]. In subsequent RCTs, researchers are expected to not only ensure consistency in the inclusion of COPD patients but also standardize the duration, frequency, and movements of Qigong so as to guarantee the high quality of the original studies. After standardizing the movements of

Table 6: Summary of evidence.

Citation	Outcomes	Studies (participants)	Heterogeneity	Relative effect (95% CI)	P value
Cao et al. [21]	FEV1	17 (1,395)	83%	MD = 0.23 (0.15, 0.31)	$P < 0.00001$
	FVC	13 (1,033)	61%	MD = 0.19 (0.08, 0.30)	$P = 0.0007$
	FEV1/FVC	20 (1,808)	74%	MD = 3.85 (2.19, 5.51)	$P < 0.00001$
	6-MWD	18 (1,562)	96%	MD = 43.83 (29.47, 58.20)	$P < 0.00001$
	SGRQ	4 (280)	54%	MD = −7.71 (−10.54, −4.89)	$P < 0.00001$
	CAT	7 (802)	78%	MD = −2.56 (−4.13, −1.00)	$P = 0.001$
Liu et al. [22]	6-MWD	10 (1,160)	66%	Hedge's g = 0.69 (0.44, 0.94)	$P < 0.001$
	FEV1	10 (809)	68%	Hedge's g = 0.47 (0.22, 0.73)	$P < 0.001$
	FEV1%	13 (1,417)	54%	Hedge's g = 0.38 (0.21, 0.56)	$P < 0.001$
	FVC	8 (674)	14%	Hedge's g = 0.39 (0.22, 0.56)	$P < 0.001$
	FEV1/FVC	13 (1,284)	53%	Hedge's g = 0.5 (0.33, 0.68)	$P < 0.001$
	Quality of life	7 (746)	77%	Hedge's g = −0.45 (-0.77, -0.12)	$P < 0.05$
Chen et al. [23]	FEV1	7 (525)	0%	MD = 0.25 (0.12, 0.38)	$P < 0.001$
	FEV1%	10 (1,005)	26%	MD = 6.71 (4.25, 9.18)	$P < 0.001$
	FVC	6 (423)	42%	MD = 0.16 (0.01, 0.31)	$P = 0.04$
	FEV1/FVC	9 (925)	71%	MD = 4.90 (2.43, 7.38)	$P < 0.001$
	CAT	5 (679)	78%	MD = −1.84 (-3.50, -0.19)	$P < 0.05$
Han et al. [24]	6-MWD	4 (346)	28%	MD = 45.27 (40.11, 50.42)	$P < 0.01$
	FEV1	5 (450)	82%	MD = 0.26 (0.14, 0.37)	$P < 0.01$
	FEV1%	7 (775)	36%	MD = 6.02 (5.02, 7.01)	$P < 0.01$
	FVC	3 (266)	0%	MD = 0.27 (0.06, 0.48)	$P = 0.01$
	FEV1/FVC	6 (423)	85%	MD = 3.63 (-0.18, 7.43)	$P = 0.06$
Li et al. [25]	FEV1/pred%	9 (985)	67%	MD = 6.86 (4.13, 9.60)	$P < 0.01$
	FEV1	4 (346)	75%	MD = 0.30 (0.14, 0.46)	$P < 0.01$
	FEV1%	8 (905)	73%	MD = 4.50 (1.84, 7.16)	$P < 0.01$
	FVC	3 (246)	0%	MD = 0.34 (0.13, 0.54)	$P < 0.01$
	6-MWD	6 (476)	92%	MD = 56.35 (37.55, 75.16)	$P < 0.01$
Xie et al. [26]	6-MWD	12 (895)	83%	SMD = 1.33 (0.97, 1.68)	$P < 0.001$
	FEV1	12 (895)	94%	SMD = 1.05 (0.56, 1.55)	$P < 0.001$
	FEV1%	15 (1,848)	86%	SMD = 0.50 (0.24, 0.76)	$P = 0.0002$
	FVC	9 (925)	68%	SMD = 0.26 (0.03, 0.50)	$P = 0.03$
	FEV1/FVC	14 (1,762)	83%	SMD = 0.44 (0.20, 0.68)	$P = 0.0004$
	CAT	3 (443)	87%	SMD = −0.56 (-1.24, 0.12)	$P = 0.11$
	SGRQ	3 (762)	81%	SMD = −1.36 (-1.74,-0.98)	$P < 0.001$
	WHOQOL-BREF	2 (852)	73%	SMD = 0.94 (0.66, 1.22)	$P < 0.001$
Xiao et al. [27]	MRC	3 (136)	62%	MD = −0.73 (-1.13, -0.33)	$P < 0.05$
	6-MWD	6 (274)	0%	MD = 17.78 (7.97, 27.58)	$P < 0.05$
	FEV1	8 (502)	83%	MD = 0.23 (0.07, 0.38)	$P < 0.05$
	FEV1/pred%	10 (580)	97%	MD = 7.59 (2.92, 12.26)	$P < 0.05$
	FEV1/FVC	12 (769)	95%	MD = 6.81 (3.22, 10.40)	$P < 0.05$
	CAT	4 (341)	56%	MD = −2.29 (-3.27, -1.30)	$P < 0.05$
	SGRQ	5 (297)	63%	MD = −9.85 (-13.13, -6.56)	$P < 0.05$

Table 6: Continued.

Citation	Outcomes	Studies (participants)	Heterogeneity	Relative effect (95% CI)	P value
Gao et al. [28]	MRC	3 (459)	42%	MD = −0.73 (-0.96, -0.50)	$P < 0.001$
	6-MWD	9 (805)	43%	MD = 21.89 (14.67, 29.11)	$P < 0.001$
	FEV1	9 (560)	5%	MD = 0.19 (0.13, 0.24)	$P < 0.001$
	FEV1%	13 (861)	57%	MD = 7.14 (6.09, 8.18)	$P < 0.001$
	FEV1/FVC	13 (890)	83%	MD = 4.2 (3.26, 5.14)	$P < 0.001$
	Quality of life	7 (780)	56%	SMD = −0.84 (-1.12, -0.55)	$P < 0.001$
Liu et al. [29]	6-MWD	5 (326)	0%	MD = 22.62 (10.49, 34.75)	$P < 0.05$
	FEV1	5 (247)	0%	MD = 0.10 (0.01, 0.18)	$P < 0.05$
	FEV1%	5 (247)	24%	MD = 3.08 (0.18, 5.97)	$P = 0.04$
Zhang et al. [30]	MRC	5 (228)	22%	MD = −0.55 (-0.75, -0.36)	$P < 0.001$
	6-MWD	9 (475)	74%	MD = 33.76 (18.99, 48.52)	$P < 0.001$
	FEV1	6 (337)	67%	MD = 0.19 (0.06, 0.31)	$P = 0.01$
	FEV1%	13 (644)	89%	MD = 6.08 (2.55, 9.62)	$P = 0.0007$
	CAT	4 (266)	4%	MD = −2.69 (-3.34, -2.03)	$P < 0.001$
Tong et al. [31]	6-MWD	8 (629)	90%	MD = 30.57 (19.61, 41.53)	$P < 0.001$
	FEV1	5 (449)	90%	MD = 0.32 (0.09, 0.56)	$P < 0.001$
	FEV1/FVC	6 (535)	47%	MD = 2.66 (1.32, 2.26)	$P < 0.001$
	FEV1%	5 (455)	61%	MD = 6.04 (2.58, 9.5)	$P = 0.006$
	CAT	3 (258)	84%	MD = −5.54 (-9.49, -1.59)	$P = 0.002$
Li et al. [32]	FEV1% (3 months)	10 (695)	36%	MD = 5.34 (2.70, 7.98)	$P < 0.001$
	FEV1% (6 months)	9 (1,006)	86%	MD = 5.35 (2.58, 8.12)	$P = 0.0001$
	FEV1/FVC (3 months)	10 (695)	66%	MD = 4.49 (1.66, 7.31)	$P = 0.002$
	FEV1/FVC (6 months)	11 (926)	79%	MD = 2.53 (0.38, 4.68)	$P = 0.02$
	CAT	5 (262)	6%	MD = −4.18 (-5.52, -2.84)	$P < 0.001$
	6-MWD (3 months)	6 (480)	45%	MD = 22.10 (12.43, 31.78)	$P < 0.001$
	6-MWD (6 months)	9 (628)	95%	MD = 44.46 (20.59, 68.34)	$P < 0.001$
Yuan et al. [33]	FEV1	4 (258)	73%	MD = 0.39 (0.21, 0.57)	$P < 0.001$
	FEV1%	4 (273)	97%	MD = 4.41 (-1.97, 10.79)	$P = 0.18$
	FEV1/FVC	8 (577)	97%	MD = 10.39 (5.44, 15.35)	$P < 0.001$
	FEV1/pred%	4 (324)	95%	MD = 8.44 (0.40, 16.48)	$P = 0.04$
	6-MWD	4 (278)	93%	MD = 63.42 (34.06, 92.79)	$P < 0.001$

Note: SMD: standardized mean difference; MD: mean difference; FEV1: forced expiratory volume in one second; FVC: forced vital capacity; 6-MWD: 6 min walking distance; FEV1/FVC: the amount of air exhaled in the first second divided by all of the air exhaled during a maximal exhalation; SGRQ: St George's respiratory questionnaire; CAT: COPD assessment test; FEV1%: percentage of the forced expiratory volume in one second; QOL: quality of life; WHOQOL-BREF: the World Health Organization on quality of life brief scale; MRC: medical research council dyspnea scale; FEV1%pred: the percentage of predicted values of FEV1.

Qigong exercises, researchers can invite professionals to train the included patients so as to improve the standard of movements and the quality of the original research.

4.3. Strength and Limitations. This overview is the first to assess the current evidence for Qigong in the treatment of COPD from the perspectives of methodological quality, reporting quality, and evidence quality in all aspects, which can provide valuable information for clinicians' decision-making as well as suggestions for the future clinical trials with SRs/MAs. However, this overview also has some limitations, and we found that most of the included SRs/MAs were of poor quality, which may lead to the low credibility of the conclusions. Besides, this overview may be undesirably subjective at certain points. Although the assessments have been assessed and reviewed by two independent assessors, different assessors may have their own judgement on each factor, so results may vary.

5. Conclusions

The available evidence suggests that Qigong appears to be an effective and safe method of treating COPD. However, problems related to the methodology, evidence and reporting quality of SRs/MAs, and original clinical trials reduced the reliability of the results. To provide convincing evidence to researchers and clinicians in this field, methodological and reporting quality of SRs/MAs shall be further improved by conducting high-quality clinical studies of Qigong for COPD.

Data Availability

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Contributions

WM participated in the research design. SHS, LPJ, WYX, and ZK conducted a literature search and screened data extraction. SHS and WM analysed the data and wrote the manuscript. LT, DCD, WL, and SGM participated in the revision of the paper. All authors read and approved the final version of the manuscript. Hongshuo Shi and Ting Liu are the co-first authors.

Acknowledgments

This study was financially supported by the Department of Higher Education, Ministry of Education, Industry-University Collaborative Education Project, Construction of Virtual Training Room for Cognitive Impairment Rehabilitation (202101312018); Natural Science Foundation of Shandong Province, China (ZR2021MH2); and Shandong Traditional Chinese Medicine Science and Technology Development Program (2019-0234).

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BioMed Research International
Volume 2022, Article ID 3755460, 11 pages
https://doi.org/10.1155/2022/3755460

Research Article

Research Trends around Exercise Rehabilitation among Cancer Patients: A Bibliometrics and Visualized Knowledge Graph Analysis

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Received 8 January 2022; Revised 2 April 2022; Accepted 6 May 2022; Published 28 May 2022

Academic Editor: Bojan Masanovic

This study analyzed the research hotspots and frontiers of exercise rehabilitation among cancer patients via CiteSpace. Relevant literature published in the core collection of the Web of Science (WoS) database from January 1, 2000, to February 6, 2022, was searched. Further, we used CiteSpace5.8R1 to generate a network map and identified top authors, institutions, countries, keywords, and research trends. A total of 2706 related literature were retrieved. The most prolific writer was found to be Kathryn H Schmitz (21 articles). The University of Toronto (64 articles) was found to be the leading institution, with the United States being the leading country. Further, "rehabilitation," "exercise," "quality of life," "cancer," and "physical activity" were the top 5 keywords based on frequency; next, "disability," "survival," "fatigue," "cancer," and "rehabilitation" were the top 5 keywords based on centrality. The keyword "fatigue" was ranked at the top of the most cited list. Finally, "rehabilitation medicine," "activities of daily living," "lung neoplasm," "implementation," "hospice," "exercise oncology," "mental health," "telemedicine," and "multidisciplinary" are potential topics for future research. Our results show that the research hotspots have changed from "quality of life," "survival," "rehabilitation," "exercise," "cancer," "physical therapy," "fatigue," and "breast cancer" to "exercise oncology," "COVID-19," "rehabilitation medicine," "inpatient rehabilitation," "implementation," "telemedicine," "lung neoplasm," "telehealth," "multidisciplinary," "psycho-oncology," "hospice," "adapted physical activity," "cancer-related symptom," "cognitive function," and "behavior maintenance." Future research should explore the recommended dosage and intensity of exercise in cancer patients. Further, following promotion of the concept of multidisciplinary cooperation and the rapid development of Internet medical care, a large amount of patient data has been accumulated; thus, how to effectively use this data to generate results of high clinical value is a question for future researchers.

1. Introduction

According to data released by the International Agency for Research on Cancer (IARC) in December 2020, there were 19.29 million new cancer cases and 9.96 million cancer-related deaths worldwide in 2020, with this then bringing about heavy health and social burdens. Furthermore, the number of new cancer cases and related deaths in China ranked first globally [1]. Therefore, the associated health problems and social concerns caused by cancer are particularly burdensome for this country.

Effective cancer diagnoses can be advanced with improved medical conditions, which are reflected in the fact that disease-related mortality and progression-free survival cannot be used to reflect multidimensional treatment effects and patient survival statuses fully. Herein, patients have high requirements

Table 1: Search strategies.

Set	Search formula
#1	TS = (exercise ∗ or "physical activity ∗" or aerobic ∗ or walk ∗ or endurance ∗ or training or yoga or pilates or tai ji or tai chi or tai − ji or tai − chi or taiji ∗)
#2	TS = (cancer ∗ or tumor ∗ or tumour ∗ or neoplas ∗ or malignan ∗ or carcinoma ∗ or adenocarcinoma ∗ or choricarcinoma ∗ or leukemia ∗ or leukaemia ∗ or metastat ∗ or sarcoma ∗ or teratoma ∗ or melanoma ∗ or lymphoma ∗ or myeloma ∗ or glioma ∗ or glioblastoma ∗ or cystadenocarcinoma ∗ or mesothelioma ∗ or neuroblastoma ∗ or osteosarcoma)
#3	TS = (rehabilitate ∗)
#4	#2 AND #1
#5	#3 AND #4

Note. TS= Topic Search.

and expectations in terms of both their treatment and rehabilitation. As such, quality of life (QOL) is increasingly being used as a primary outcome measure for evaluating cancer treatment effects, long-term survival, and functional status among survivors in contemporary research [2, 3].

Exercise is one method that has been found to improve the prognosis of numerous cancer patients and increase their overall QOL [3–5]. The World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), the American Cancer Society (ACS), and the National Cancer Institute (NCI) all recommend that cancer survivors maintain adequate levels of physical activity after treatment to maintain their overall health [6–9]. Previous studies have also outlined the critical role of exercise as a "prescription" for various chronic noncommunicable diseases [10–12].

Due to an extraordinary abundance of literature on this topic, the classification and summary of related research using more traditional reading methods often have certain limitations. Following the improvement of computer technologies and bibliometrics, software to visualize document information that allows for the drawing and analysis of scientific data has been gaining increased attention. In this context, bibliometrics [13, 14], visualized scientific knowledge graphs [6, 15, 16], and their related applications in bibliometrics are no longer the exclusive branches of information science and information management science. They are also being applied within the natural science, humanities, and societal concerns. In the context of scientometrics, methods for data and information visualization—as based on Thomas Samuel Kuhn's paradigm [7–9], Derek John de Solla Price's s scientific frontier theory, Bo Ronald S. Burt's structural hole theory [17], Kleinberg's burst detection technology, the optimal foraging theory (OFT) [18–21], and Chinese knowledge unit discrete and reorganization theory [22]—have been produced and developed by CiteSpace [23, 24] and other citation visualization analysis software. With the rapid growth of contemporary scientific research and published literature, visual analysis software provides a strong convenience for scientific researchers to use existing data to refine and extract new knowledge. Kuhn believes that the essence of scientific development is the iterative movement process of conventional science and scientific revolution, as well as between the accumulation paradigm and cross-revolution paradigm; as such, examining both emerging and classic literature provides a turning point for science as a whole. Derek John de Solla Price's scientific frontier theory is based on both Bernard's "Network Thinking of Scientific Development Model" and the Science Citation Index (SCI) and assumes that the research frontier is based on recent research results. Further, structural holes are measured in CiteSpace using the betweenness centrality of nodes in the more comprehensive network; herein, a sudden increase in frequency indicates the criticality of a given research topic. The original knowledge map was based on the laws of scientific development in mathematical equations and was then used to display simple curves or two-dimensional graphics. The best information foraging theory and Hidden Markov Model (HMM) [25] provide a new foundation for the vision-oriented integration strategy. With the help of the knowledge map as optimized by the presentation model, researchers can now see through the complex structures of various fields into the broader knowledge system, allowing them to clarify the complex knowledge networks formed by information explosions. The use of computer software to process documents using bibliometrics, visualized scientific knowledge maps, etc. can either replace or enhance scientific researchers' repetitive mental work and further liberate and stimulate scientific research productivity [26].

To understand the research results and trends of the effects of exercise therapy in cancer rehabilitation, we used bibliometrics and visual knowledge graph analytical methods to display the relevant research status allowing for the exploration of novel development laws and new research hotspots. The core concepts of CiteSpace—the visualization research software used in this study—include burst detection, betweenness centrality, and heterogeneous networks, which all help to visualize ongoing research frontiers, research statuses, hotspots, and the prompt discovery of new research trends [23, 27].

2. Materials and Methods

2.1. Literature Sources and Search Strategies

2.1.1. Literature Sources. In this study, the core collection of the Web of Science (WoS) database was used as its source of the literature, with the last updated search time being on February 6, 2022. As a global authoritative citation database, WoS includes more than 11,000 authoritative and high-

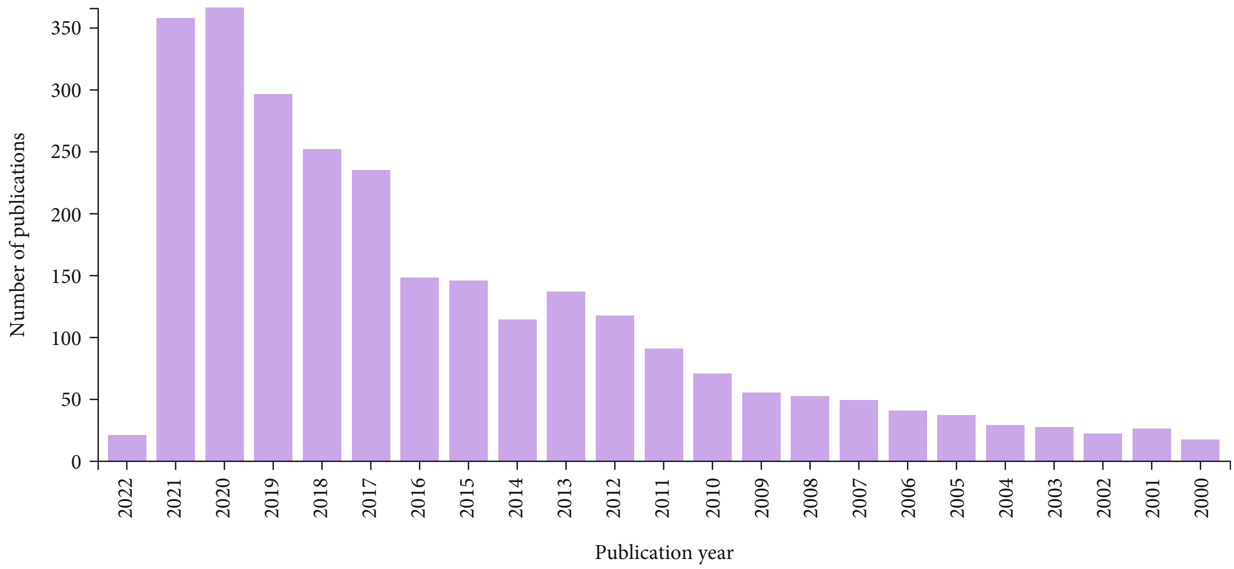

Figure 1: Annual trends in the number of publications from 2000 to 2022.

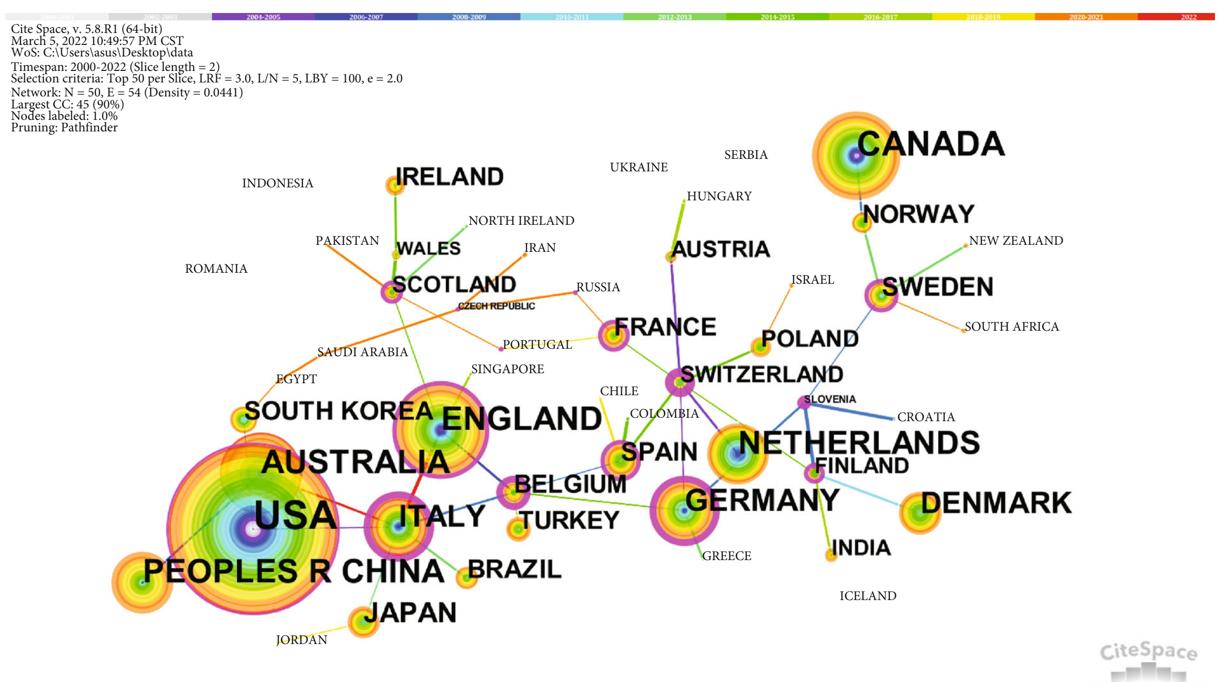

Figure 2: The co-country network of co-country.

impact international academic journals, covering the fields of the natural sciences, biomedicine, engineering technology, social sciences, arts, humanities, etc. Its powerful analysis function also helps researchers to more effectively grasp relevant topics and search for breakthroughs and innovations in research. Furthermore, it allows them to find high-impact papers quickly, discover research directions that their peers are concerned with, and identify the development of research trends in a given field. These characteristics make WoS a popular database for bibliometric research. WoS also contains references cited in papers and compiles a unique citation index that includes the author, article source, and year of publication [28]. Therefore, this study adopted WoS as its database.

2.1.2. Search Strategies. We conducted our searches according to the retrieval strategies shown in Table 1 and collected articles from the core collection of the WoS database from January 1, 2000, to February 6, 2022. The search terms used include "exercise," "tumor," and "recovery."

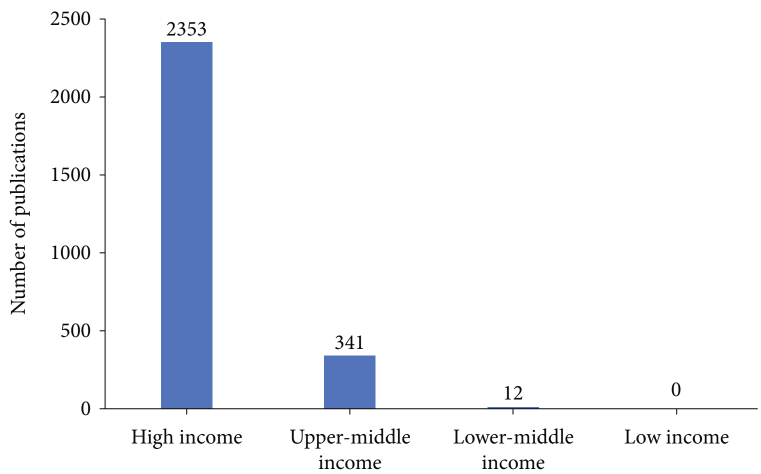

FIGURE 3: Number of articles published across the different international economic groups.

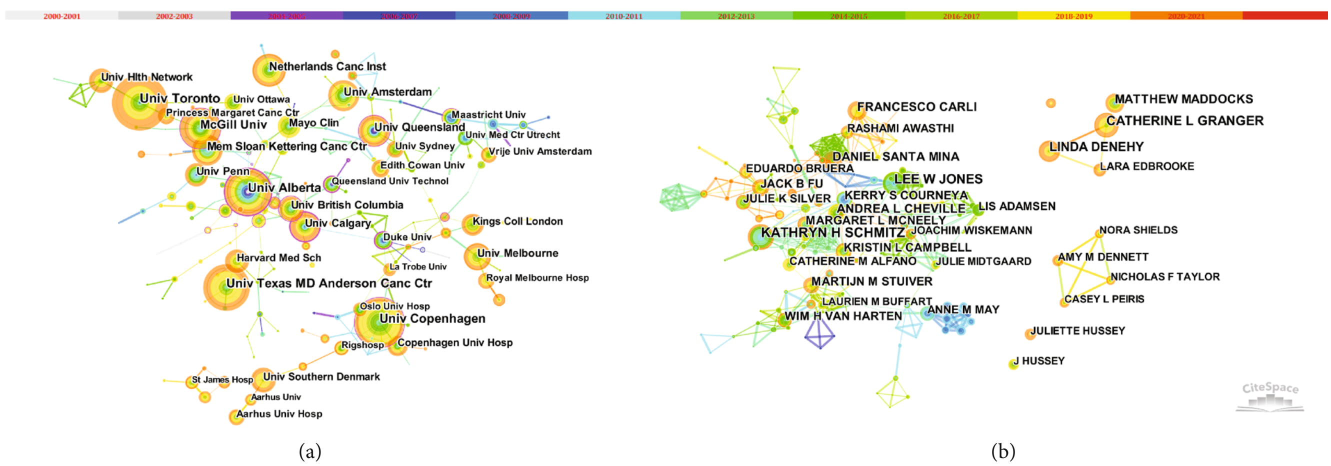

FIGURE 4: (a) The co-institution network; (b) the co-author network.

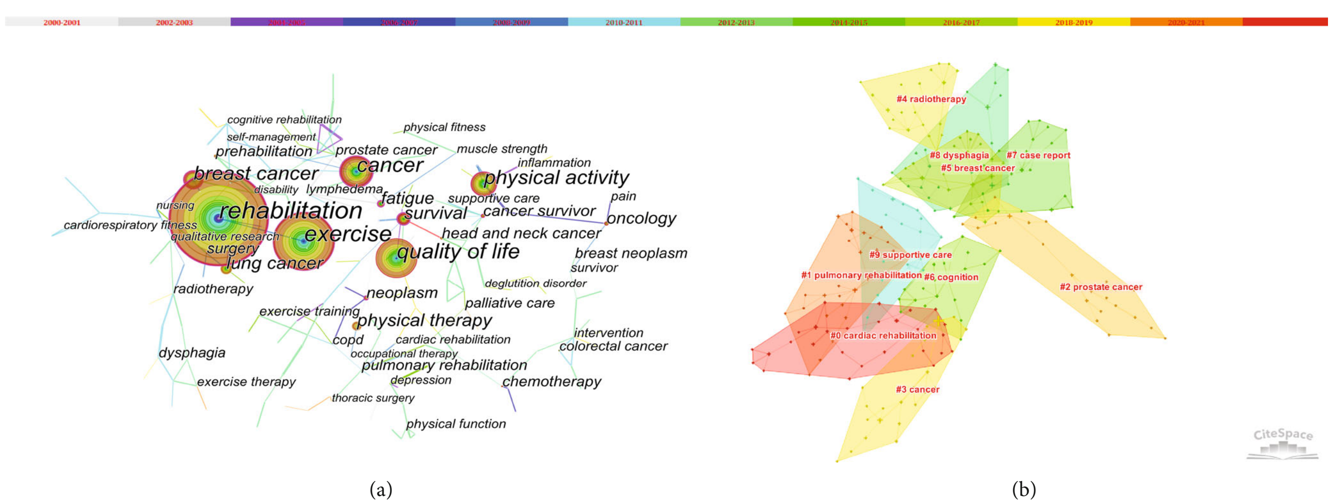

FIGURE 5: (a) The co-occurring keywords network; (b) the co-occurring keywords cluster network.

2.2. Inclusion and Exclusion Criteria. We downloaded and imported the retrieved information into the literature management software EndNote 20, which included primary research, clinical research, and reviews related to exercise-based rehabilitation for cancer patients. We then eliminated duplicate literature, patents, seminar reports, conference

Table 2: Top 10 keywords in terms of their frequency and centrality.

Rank	Frequency	Keyword	Centrality	Keyword
1	772	Rehabilitation	0.77	Disability
2	498	Exercise	0.74	Survival
3	351	Quality of life	0.72	Fatigue
4	294	Cancer	0.61	Cancer
5	238	Physical activity	0.6	Rehabilitation
6	195	Breast cancer	0.59	Exercise
7	126	Lung cancer	0.48	Function
8	125	Survival	0.47	Neoplasm
9	123	Physical therapy	0.45	Breast cancer
10	95	Fatigue	0.42	Nursing

abstracts, edited materials, and other nonresearch papers. Studies related to animal experiments were also been excluded.

2.3. Visualization and Statistical Analyses. Documents that satisfied our inclusion criteria were included in text format, along with their full documentation and citations that were in turn named "download_1-5." The output documents were then imported into the visual analysis software CiteSpace5.8.R1. After time slicing and thresholding, modeling, pruning, merging, mapping, and other analytical steps [29], the subject headings, authors, author units, countries or regions of origin, date of publication, and additional information were extracted for analysis. The results are presented in graphs, with different nodes representing various elements, including factors like countries, institutions, and keywords, with their sizes reflecting the number or frequency of publications herein [30]. Links between nodes represent the relationship between them, including factors like collaboration, co-occurrence, or coreference. The colors of the nodes and the connecting lines represent different clusters or years [31]. In addition, the centrality index was used to evaluate each source's journal, author, institution, or country. In network maps, a node with a high degree of centrality indicates that it is highly connected to other nodes or lies between two different sets of nodes. The purple outer ring reflects a node with a centrality greater than 0.1, which indicates that it has a significant impact [32]. The resulting data were analyzed using Microsoft 365 Excel and IBM SPSS Grad Pack v27 [33]. A p-value of <0.05 was considered statistically significant.

3. Results and Discussion

3.1. Literature Analysis. We included 2706 articles that satisfied our criteria, with the results showing a fluctuating upward trend in the number of publications from 2000 to 2022. From 2016 to 2017, specifically, the number of related publications showed its largest increase (87 articles), indicating that, from 2016, increasing numbers of researchers began to focus on exercise-based rehabilitation in cancer patients. However, when compared with the data in 2020, the number of related publications in 2021 decreased by 8, which was likely due to the COVID-19 pandemic in Europe and the United States, which resulted in a reduced production of research in regions and countries that would have typically produced more articles (Figure 1). In a trend analysis of the number of publications over the study period, we found that the increase in publications was statistically significant overall ($p = 0.006$).

3.2. Collaborative Network of Countries, Institutions, and Authors. As shown in our visualization, the top 5 countries with the most significant number of publications are the United States (729 articles), Canada (273 articles), the United Kingdom (230 articles), Australia (222 articles), and the People's Republic of China (221 articles). Among these, the centrality of the United States and the United Kingdom both exceed 0.1, indicating the essential contributions of these two countries in this field. Conversely, although Canada, Australia, and China are also in leading positions in terms of their number of articles published, the centrality of these countries is low, which indicates that the quality of articles published in these regions still has to be improved (Figure 2).

According to the new regulations for the division of countries based on different income groups as announced by the World Bank on July 1, 2021, nations have been divided into low income (gross national income per capita, GNIPC <1046 US dollars), lower-middle income (GNIPC 1046-4095 US dollars), upper-middle income (GNIPC 4096-12695 US dollars), and high income (GNIPC >12695 US dollars). Among these, high-income countries have contributed more than three-quarters of the total publications (2,353) internationally, which is then followed by upper-middle income countries (341) and lower-middle income countries (12), with no publications on this topic originating from low-income countries (Figure 3) [34]. This phenomenon means that a country's economic situation affects its publishing ability.

Research institutions with the highest number of publications include the University of Toronto, Canada (64 articles), the University of Copenhagen, Denmark (58 articles), the University of Alberta, Canada (58 articles), the University of Texas MD Anderson Cancer Center, USA (55 articles), and McGill University, Canada (50 articles) (Figure 4(a)). The inter-agency cooperation relationship herein shows a relatively localized trend, indicating that multiagency and cross-regional cooperation need to be strengthened.

Figure 4(b) depicts the network of the co-authors. The author with the highest number of papers is Kathryn H Schmitz from the University of Pennsylvania, USA, with 21 articles, who is then followed by Catherine L Granger from the University of Melbourne, Australia (19 articles), and Lee W Jones from Memorial Sloan Kettering Cancer Center, USA (19 articles). Like institutional cooperation, the author cooperation network also shows a localization trend, with the centrality of authors being low overall, indicating that sufficient, extensive, and high-quality collaboration between authors needs to be strengthened in future.

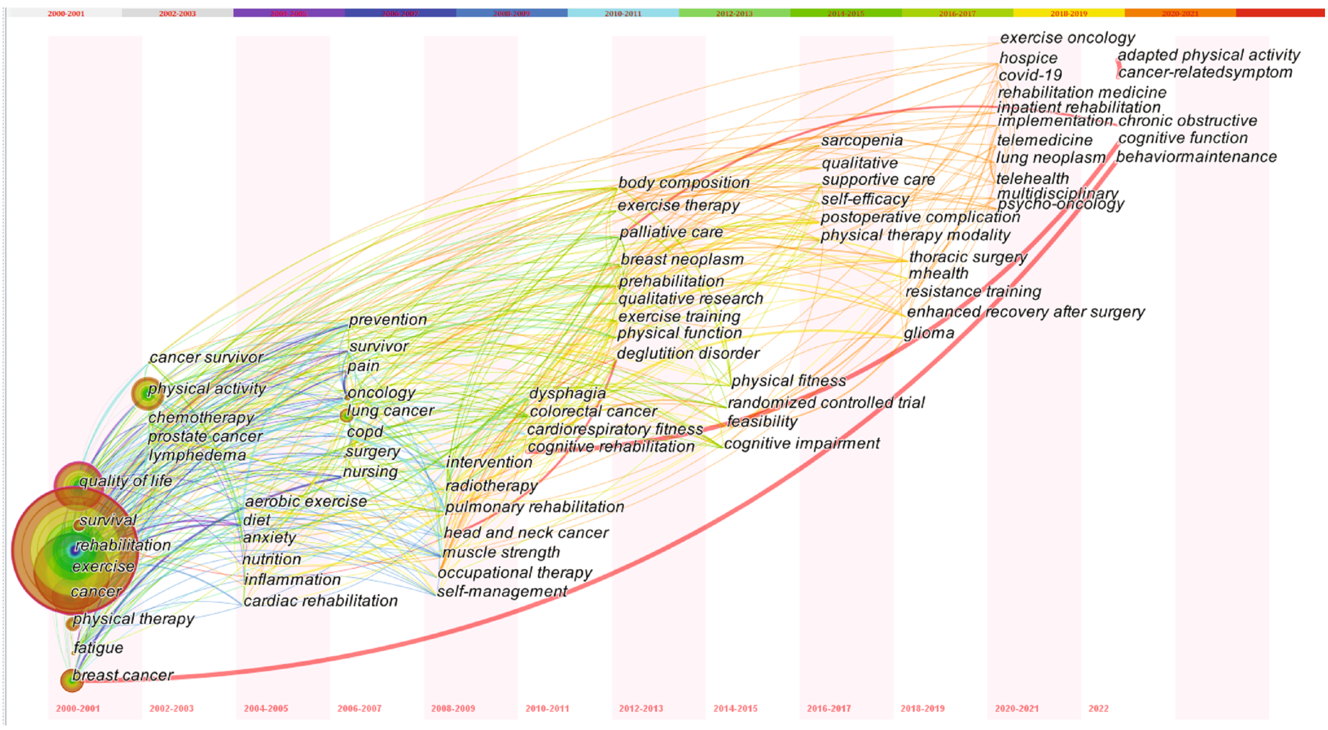

FIGURE 6: Time zone network for the keywords.

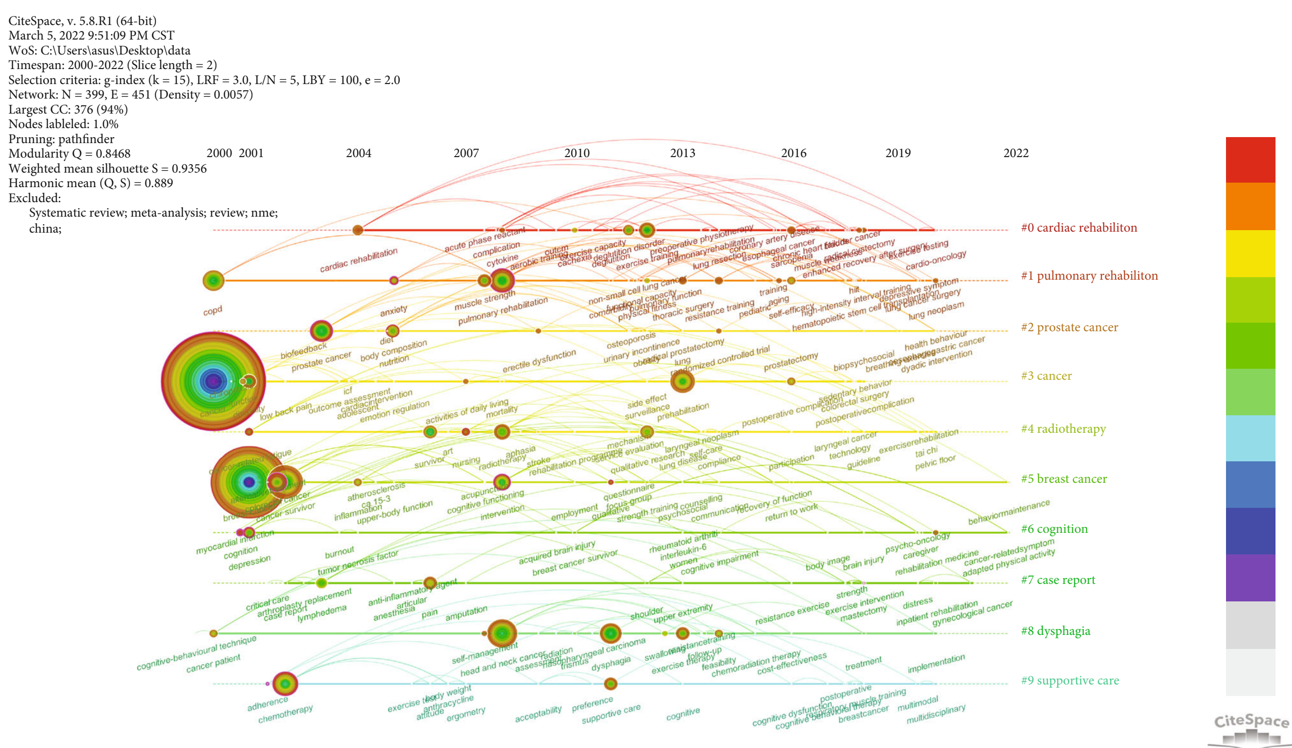

FIGURE 7: Timeline network of the keywords.

3.3. Keyword Co-Occurrence and Cluster Analysis. Figure 5(a) depicts the co-occurring keywords network; in order to analyze the co-occurrence of keywords more clearly, here Table 2 lists the top 10 keywords in terms of their high frequency and centrality. These keywords reflect ongoing research hotspots within the topic of exercise-based rehabilitation for cancer patients. The co-occurring keywords were analyzed using a log-likelihood ratio to generate 10 clusters, which included the following: "cardiac rehabilitation," "pulmonary rehabilitation," "prostate cancer," "cancer,"

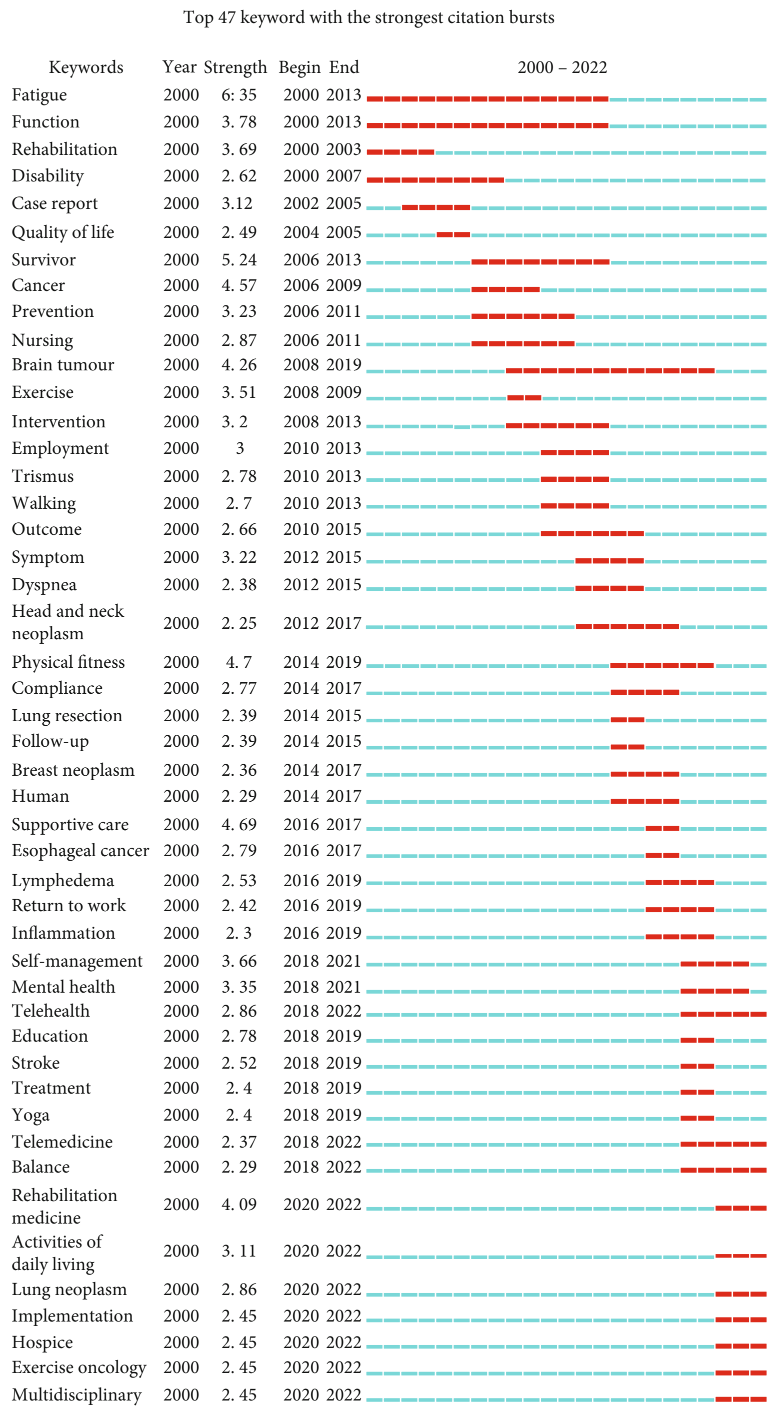

Figure 8: Top 47 keywords with strongest citation bursts.

"radiotherapy," "breast cancer," "cognition," "case report," "dysphagia," and "supportive care" (Figure 5(b)).

3.4. The Evolution of Keywords over Time. The temporal evolution of keywords in the included literature was also analyzed. On the whole, the hotspots changed from "quality of life," "survival," "rehabilitation," "exercise," "cancer," "physical therapy," "fatigue," and "breast cancer" to "exercise oncology," "COVID-19," "rehabilitation medicine," "inpatient rehabilitation," "implementation," "telemedicine," "lung neoplasm," "telehealth," "multidisciplinary," "psycho-oncology," "hospice," "adapted physical activity," "cancer-related symptom," "cognitive function," and "behavior maintenance." The research on cancer has expanded from early studies of breast cancer to those on other types of tumors. Due to the rapid development of the Internet, medical treatment has also shifted from being primarily short-distance to a combination of near-telemedicine treatment, with greater emphasis being placed on the concept of precision treatment (Figure 6).

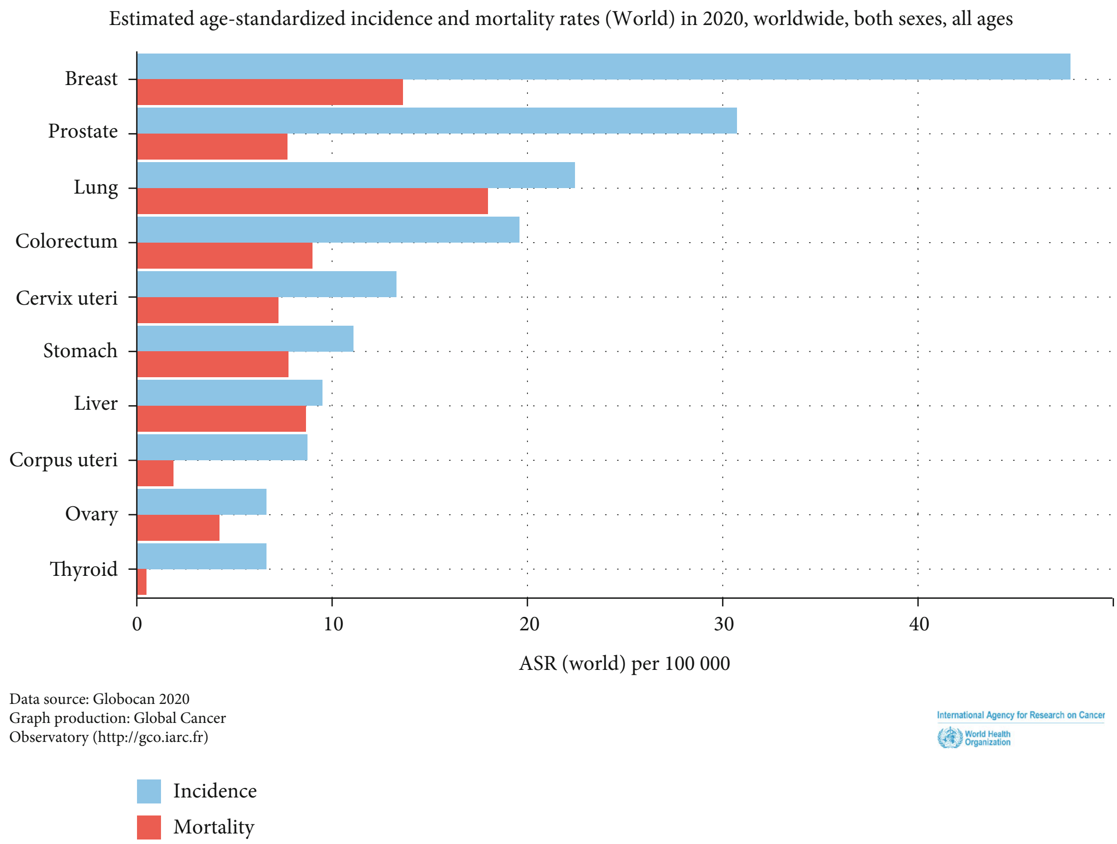

Figure 9: Estimated international age-standardized incidence and mortality rates of various cancer types in 2020 across both sexes and all ages. Source: IARC data visualization exploration [1, 39, 40].

In a timeline plot containing the cluster information (Figure 7), a shift is seen in research hotspots from cardiorespiratory function to generalized physical function and from earlier research on depression and anxiety to an emphasis on supportive care. In addition, recent studies on enhanced recovery after surgery and elderly patients are likely to become a new research hotspot.

Figure 8 shows the top 47 keywords with the strongest citation bursts. The segmented blue line represents the time interval, with the red line representing the most substantial period of each keyword's burst [35]. The top three keywords with the strongest citation bursts are "fatigue," "survivor," and "physical fitness," indicating that the symptoms, recovery, and long-term survival of cancer patients have consistently been the focus of research by experts in the field of oncology rehabilitation. The three keywords "fatigue," "function," and "disability" arose early in the dataset and lasted for around ten years. Another keyword that appeared in the early stage was "rehabilitation"; however, it only lasted for three years. The reason for this may be that rehabilitation medicine had not been well developed, meaning that research related to it has not been carried out smoothly. The most cited keywords in terms of the bursts appearing in 2020 are "rehabilitation medicine," "activities of daily living," "lung neoplasm," "implementation," "hospice," "exercise oncology," and "multidisciplinary." All of these then continued into 2022 and may even become new hotspots in the field. In addition, researchers' focus on the keywords of "telehealth," "telemedicine," and "balance" has also continued into 2022.

4. Conclusions

We used CiteSpace to perform a bibliometric analysis of 2706 global scientific results on exercise rehabilitation for use among cancer patients published from 2000 to 2022 using multiple perspectives, following which we presented the results in knowledge network maps and tables. This study's results show that, from 2000 to 2022, academic attention in exercise rehabilitation for use among cancer patients has experienced a steady growth trend and will likely continue to receive a good deal of attention with the ongoing development of rehabilitation medicine. In addition, it is worth noting that the roles of adapted physical activity, cognitive function, and behavior maintenance in the research body of this field are becoming increasingly prominent, which means that they may become prospective avenues for the development of this field. In addition, the most productive author found was Kathryn H Schmitz from the United States. Additionally, the United States and Canada are the two most significant contributors herein. Correspondingly, most of the institutions with a large number of publications are from these two countries, among which the University of Toronto and the University of Texas MD Anderson Cancer Center are among the top in terms of their

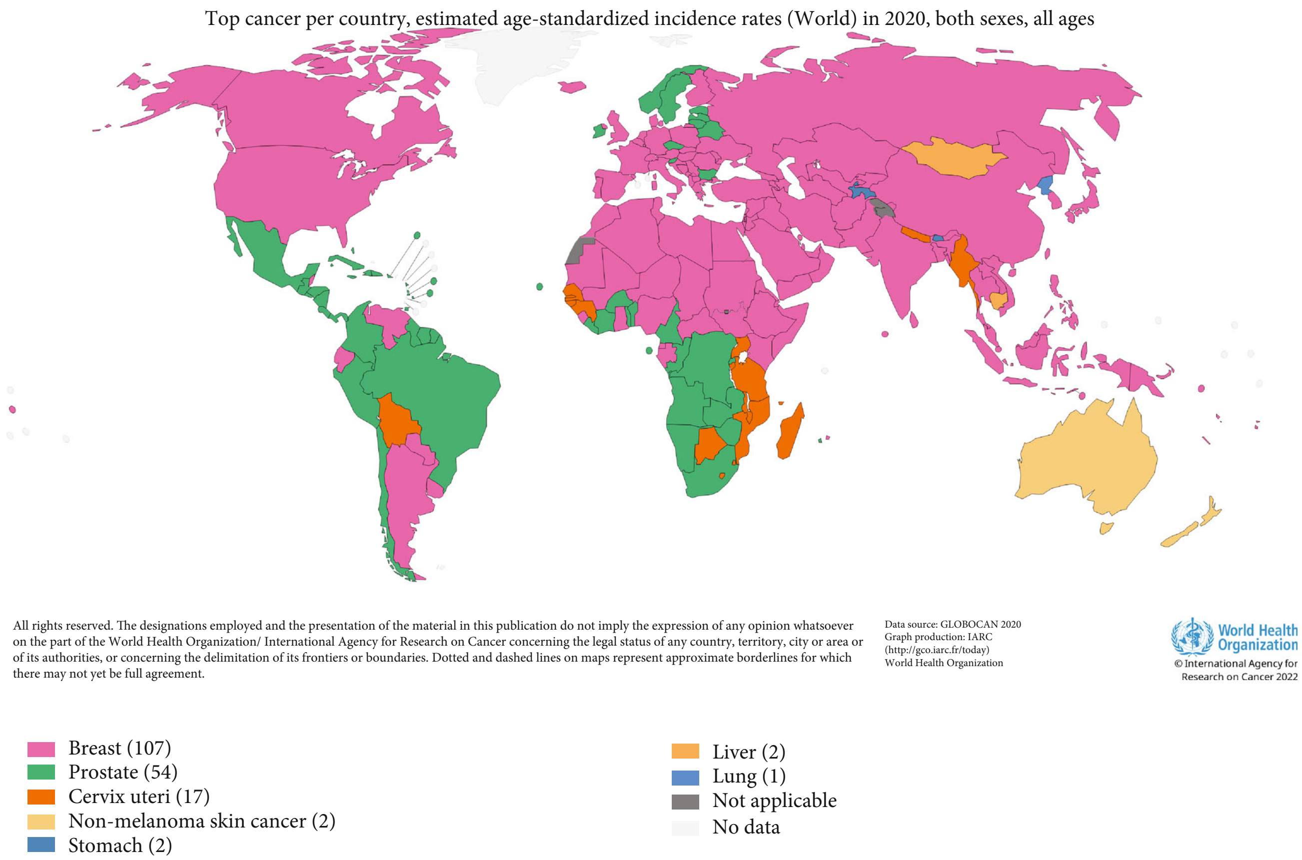

Figure 10: Top cancer type per country and the international estimated age-standardized incidence rates in 2020 for both sexes and all ages. Source: IARC data visualization exploration [1, 39, 40].

number of publications. Our examination into keywords with citation bursts showcased that "rehabilitation medicine," "activities of daily living," "lung neoplasm," "implementation," "hospice," "exercise oncology," "mental health," "telemedicine," and "multidisciplinary" may be potential directions for future research.

As early as 1993, Hoffman [36] mentioned the phrase: "exercise is medicine" (EIM) in a paper, with this concept then being widely used in the prevention and treatment of various chronic noncommunicable diseases. In 2007, the American Medical Association (AMA) and the American College of Sports Medicine (ACSM) jointly launched an EIM project focusing on increasing participants' physical activity (PA) and promoting their health through the use of appropriate exercises [37]. The critical role and clinical recommendations of EIM in terms of treating tumors have also attracted increasing attention. The United States is the country with the most significant number of publications herein, which may be related to its earlier proposals and initiatives. In addition, in the latest data released by the World Bank, the United States ranks first in terms of its gross national income per capita and gross domestic product. Further, the literature has confirmed that there is a significant positive correlation between national economic size and scientific productivity [34, 38], which may be another reason why the United States is the country with the largest number of publications in this field. Although the total number of articles published by Chinese scholars ranks in the forefront of this area, the number of articles published by its core authors is relatively small, with the centrality of its cooperation network being low. As such, increased encouragement and promotion of academic exchange activities among scholars in related fields across different countries, as well as the development of domestic and foreign cooperative relations, the improved scientific research, the sharing of research results, and the joint promotion of the development of exercise rehabilitation among cancer patients, are all needed.

From our analysis of keywords, certain cancer types (breast, lung, and prostate cancer) received sufficient attention and research in the early stage of this field's development, which may be related to the high incidence and mortality of these three cancers in the wider population (Figure 9) [1, 39, 40]. In terms of the (estimated age standardized) incidence rates worldwide, these are also the three most common cancer types overall. The results of our bibliometric analysis revealed that, when compared with other types of cancer, there are more research reports related to these three malignant tumors, with the research hotspots about them having developed at an earlier stage. The results of our bibliometric analysis are consistent with the findings of international statistics. Breast and prostate cancer are the "number one cancers" with the highest incidence rates in most countries internationally (Figures 10) [1, 39, 40], which is enough to draw the attention of local medical institutions and health policy departments in their investment in research related to these two cancers.

QOL is another concept that is generally emphasized in the literature. For example, the fatigue-related symptoms of cancer patients have been researched in detail, with there being more studies linking specific cancer types with physical therapy. However, only high-intensity interval training has been studied for use within specific exercise intervention methods. An earlier paper [41] reviewed various types of cancer survivors who exercised regularly, such as through the use of endurance and aerobic training, supervised and home training, recreational PA, and nonrecreational PA, with them finding that PA reduces the risk of certain cancers. Herein, survivors are able to reduce their risk of disease recurrence and increase their chance of prolonged survival, in addition to improving their overall QOL, both during and after treatment. However, cancer survivors still generally lack any significant levels of PA. Furthermore, many medical professionals, patients, and caregivers lack knowledge of exercise programs, doubt the safety or suitability of exercise programs, or have a low compliance with guidelines [42]. As such, more research on different exercise intervention methods is needed to provide more diversified and reliable treatment options.

The types of studies included in our literature search include systematic reviews, qualitative studies, and controlled trials, among which clinical trials were most prominent in 2010-2018. While promoting the concept of EIM in clinical practice after considering its potential benefits for patients, how to further explore and obtain high-quality, evidence-based medical evidence has become a problem to which scientific researchers should pay more attention.

This study does possess several limitations, such as the fact that the core collection of the WoS database was the only data source used due to its inherent advantages, meaning that other databases like PubMed, Scopus, and Google Scholar were not included. Second, there was a lack of non-English database literature and a potential bias resulting from our use of self-citation. Nonetheless, our study comprehensively outlines the current status of research on exercise rehabilitation, as well as the frontiers aimed at cancer patients that have developed from 2000 to 2022, which then provides possible directions for future research. Therefore, the bibliometric analysis of this study will be helpful to relevant scholars, clinicians, and students.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Yun Pan and Xianyu Deng are the authors that contributed equally.

Acknowledgments

This study was supported by grants from the National Natural Science Foundation of China (No. 82072647).

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Hindawi
BioMed Research International
Volume 2022, Article ID 7525262, 5 pages
https://doi.org/10.1155/2022/7525262

Research Article

Participation of Soccer Training Improves Lower Limb Coordination and Decreases Motor Lateralization

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Received 25 March 2022; Accepted 21 April 2022; Published 30 April 2022

Academic Editor: Bojan Masanovic

Athletes, who display less lateralization, are considered to be more successful in their sports. Therefore, it is important to test the lateralization profiles of the athletes to determine future prospects. Soccer is one of the sports where lateralization plays an important role because performing the passes and kicks with either foot may increase the success rate. Improved lower limb coordination is also very essential to perform the soccer skills more efficiently. Thus, the purpose of this study was to investigate the motor lateralization profiles of youth soccer players and to compare the same lateralization to non-athletes. A total of 28 healthy youth (14 soccer players) aged between 14 and 16 years voluntarily participated in this study. All participants were right-footed and were asked to hit the targets with their either foot maintaining accuracy in a custom-made virtual reality interface. Final position error (FPE) and foot path deviation from linearity (FPDL) were calculated to test motor lateralization for each foot and group. Two-way Mixed Model ANOVA was conducted for each dependent variable. Results indicated significant differences for FPDL between groups, while there were no significant differences between groups and within feet for FPE. Nonathletes had significantly higher FPDL with their nondominant foot compared to their dominant foot, which was not observed among soccer players. Overall, nonathletes' movements were more curvature path compared to soccer players, thus, can be considered as less coordinated. As soccer players did not show a difference between their feet on FPDL and performed better than nonathletes, soccer participation can improve lower limb coordination as well as alter motor performance and lateralization.

1. Introduction

Soccer is one of the most popular sports in more than 200 countries [1]. Approximately 270 million people (4% of the world population) actively participate in soccer [2, 3]. This popularity may be due to the fact that both gender like watching and playing it in a wide age range, and it does not require any specific physical features and anthropometric parameters at the amateur level. In contrast to the amateur level, playing soccer at expert-level requires highly developed physical capacities, psychological factors, perceptual, cognitive, and motor skills such as running, jumping, heading, kicking, passing, dribbling, and balance [3–5]. All of those capacities are determined player's performance level with (i.e., passing, shooting, heading, controlling, and dribbling) and without the ball (i.e., running, walking, and jumping) in a soccer match [4, 6]. Additionally, technical skill is also known as specific motor skill (i.e., passing, shooting, heading, controlling, and dribbling) and assessed according to kicking performance by measuring some parameters such as kicking accuracy and ball velocity [7, 8]. Further, the ball accuracy and velocity are affected by leg preference [9]. Leg preference or footedness is defined as the tendency to select one leg for various motor functions in opposed to other in performing motor tasks, such as kicking a ball [9, 10]. Previous research focused on the functional advantages of the dominant leg over the nondominant one for accuracy [11], kicking speed [8, 12, 13], reaction time [14], and balance [15]. These findings suggest that each foot was used for different tasks [16]. For example, in the process of kicking or passing, the dominant leg is preferred to perform kicking while the nondominant leg is preferred to provide balance (stabilization) [16]. 79.2% of top-class soccer players in FIFA World Cup 1998 preferred their dominant foot in mobilization skills (i.e., free kick, penalty kick, corner kick, and goal kick) to perform the tasks more accurately and powerfully, while the nondominant foot was preferred only in passing when it is required.

Whereas a human body was created as a symmetric structure, functional movements could be asymmetric between two limbs [16–19]. When there are a 10% or more differences between two limbs in a movement quality (force, power, or muscle girth), it is assumed that motor lateralization exists [11]. Motor lateralization was also related to neural control, explained by a theory called "dynamic dominance of motor lateralization." According to this theory, the left hemisphere/right arm is specialized for coordination while the right hemisphere/left arm specialized in the stabilization of the movement [19]. This specification may be also valid for the legs as there was a significant association between handedness and footedness dominance [20–22]. As stated above, motor lateralization should play an important role in soccer as the dominant leg performs most of the skills more accurately and powerful than the nondominant one [11]. Even though soccer players display lateralized behaviors when preferring a foot to execute passing or shooting skills, it has been previously shown that less lateralized behaviors are considered to be an efficient factor in order to be a professional soccer player [11, 23–25]. Therefore, one of the common features of top-class soccer players about lateralization is that they have applied extensive soccer-specific training to use both feet very well, and thus, they become less lateralized players [9, 16, 23]. The effect of lateralization on performing movements is important and plays a major role in soccer performance. Especially, the youth period is very important for learning new movement patterns with both feet so that the player could be more successful to perform those skills during the game-like situation [1]. In this regard, it was thought that the lateralization level of the soccer players should be determined in the beginning of the youth period to develop the bilateral competence of each foot for better motor performance [26]. Moreover, it is also important to measure if long-term participation in soccer training may alter motor lateralization. Therefore, the purpose of this study was to investigate motor lateralization profiles between youth soccer players and youth nonathletes.

2. Materials and Methods

2.1. Participants. A total of 28 healthy male participants aged between 14 and 16 years volunteered in this study. Fourteen participants were soccer players ($M_{age} = 14.79 \pm 0.80$ years), and fourteen age-matched ($M_{age} = 14.93 \pm 0.73$ years) control participants had no training experience in any sports. Soccer players had 3-5 years of soccer playing experience. Participants were determined as a convenience sampling method and were recruited from the local soccer teams. All participants were right dominant footed, which was determined by kicking a ball [27]. All individuals and their parents signed the consent form approved by the Institutional Review Board of the Nevsehir Haci Bektas Veli University (permit no: 2018.10.110), and the study was conducted according to the declaration of Helsinki as amended by the World Medical Association Declaration of Helsinki.

2.2. Experimental Setup and Task. Participants stood on a 20 cm height platform from the ground with either leg parallel to a 55" LCD TV, which is located 2 m away from the participants (Figure 1) and 10 cm above the ground. A sensor of the electromagnetic movement tracker (TrackSTAR, Ascension Technology, USA) was placed on the participants' big toes of the foot being measured. A simultaneous 2D view of the kicking leg was provided to the participants as a visual feedback. A custom-made virtual reality interface provided a cursor representing tip of big toe, a start circle, and 3 different targets on the feedback screen. The cursor represented the tip of the big toe of each foot, and its position on TV was updated in real time, which was 100 Hz.

Three targets (0^0, 10^0, and 20^0 from the start circle) were presented in a randomized order, and the task was to hit these targets with considering accuracy. One target was displayed for each trial. The start circle with a diameter of 3 cm was aligned with the height of the supporting platform and was 30 cm away from the starting position. Targets were displayed as 5 cm in diameter. The cursor was 1.5 cm in diameter with cross hair. There was an audio go signal with visual information upon which participants were asked to move to the target. The participants had to put the cursor inside the start circle for 300 milliseconds to initiate the movement. The task was to move the cursor to each target in 1-sec duration. The initiation of the movement was self-paced, thus, the participants had enough time for the movement planning. Participants performed a total of 20 trials for each target. Thus, each participant made 60 trials with their each foot. For motivational purposes, the accuracy of each trial was rewarded with 10, 3, and 1 point for locating 5 cm, 6 cm, and 7 cm diameter from the center of the displayed target, respectively. The task was performed by each foot, and the foot being tested was counterbalanced among the participants.

2.3. Data and Statistical Analysis. To determine motor lateralization, two measures were defined: (1) movement accuracy that was defined as final position error (FPE), and (2) movement quality that was defined as foot path deviation from linearity (FPDL). The FPE was calculated as the Euclidian distance between the last point of the tip of the big toe represented by the cursor and the center of the target. The FPDL was calculated as the ratio between the minor and major axis of the foot path of the big toe. It is considered to be a measurement of coordination. The less values for the FPDL represent more linear movement. Data collection and analysis were performed using custom-made Matlab software.

For statistical purposes, the mean value of each dependent variable was calculated, and analysis was performed for each dependent variable. Two-way mixed model ANOVA was conducted to test if each dependent variable was different within the foot and between the groups using IBM SPSS Statistics (Version 23 for Windows; IBM, Armonk, NY, USA). Thus, foot (dominant and nondominant) was treated as a within-factor, and groups (youth

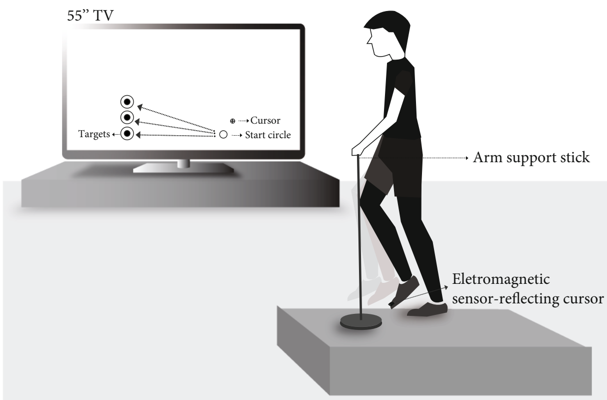

Figure 1: Experimental setup.

soccer players and nonathletes) were treated as a between-factor. The student's t-test with Bonferroni correction was conducted for post hoc analysis. The statistical significance level was set as $p < 0.05$.

3. Results

Figure 2 displays the mean value of final position error (FPE) for dominant and nondominant foot and groups (youth soccer players and nonathletes). Overall, both groups displayed similar performance between feet in terms of FPE. A 2-way mixed-model ANOVA with foot as within-factor and groups as between-factor revealed no significant main effects and nor interaction, $F_{(1,26)} = 0.61$, $p = 0.87$, and $\eta^2 = 0.02$ for foot main effect; $F_{(1,26)} = 0.07$, $p = 0.93$, and $\eta^2 = 0.003$ for group main effect; $F_{(1,26)} = 0.02$, $p = 0.97$, and $\eta^2 = 0.001$ for foot x group interaction.

Figure 3 shows the mean value of foot path deviation from linearity (FPDL) for dominant and nondominant foot and groups (youth soccer players and nonathletes). Youth soccer players had similar FPDL performance for dominant and nondominant foot, which was not observed in youth nonathletes. A 2-way mixed model ANOVA displayed a significant foot main effect, $F_{(1,26)} = 11.66$, $p < 0.01$, and $\eta^2 = 0.31$; a significant group main effect, $F_{(1,26)} = 4.01$, $p < 0.05$, and $\eta^2 = 0.13$; and a foot x groups interaction $F_{(1,26)} = 9.11$, $p < 0.05$, and $\eta^2 = 0.26$. The dominant foot's FPDL ($M = 0.087 \pm 0.014$) was significantly better than the nondominant foot ($M = 0.097 \pm 0.019$). Youth soccer players ($M = 0.086 \pm 0.018$) had better FPDL than youth nonathletes ($M = 0.098 \pm 0.016$).

Post hoc analysis for two-way interaction displayed that in nonathletes, the nondominant foot ($M = 0.11 \pm 0.015$) had significantly larger FPDL than the same group's dominant foot ($M = 0.088 \pm 0.011$), while they were larger than the values obtained from soccer players' both feet ($M_{\text{Dominant}} = 0.086 \pm 0.018$ and $M_{\text{Nondominant}} = 0.087 \pm 0.019$). Moreover, there was no significant difference in FPDL between feet in youth soccer players.

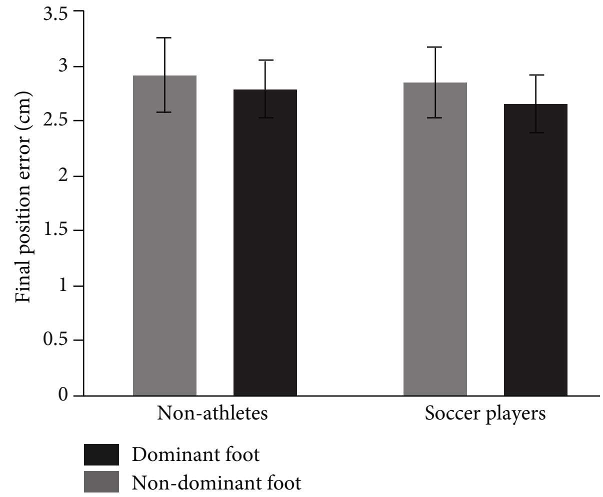

Figure 2: The mean value of final position error (FPE) for dominant (black in color) and nondominant foot (grey in color) and groups (youth soccer players and nonathletes).

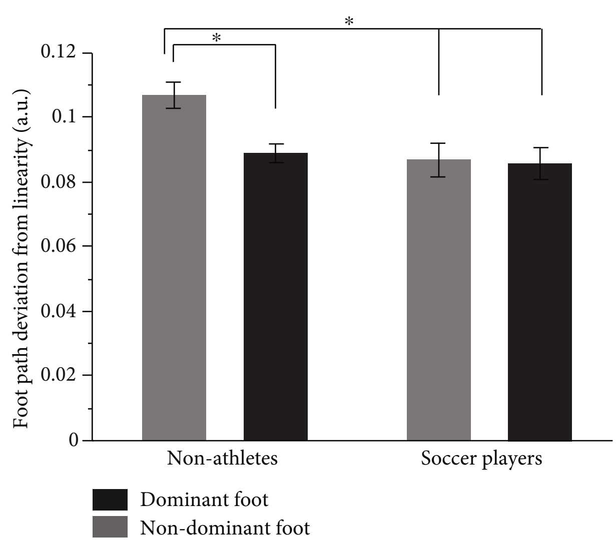

Figure 3: The mean value of foot path deviation from linearity (FPDL) for dominant (black in color) and nondominant foot (grey in color) and groups (youth soccer players and nonathletes). * represents $p < 0.05$.

4. Discussion

This study investigated motor lateralization profiles of youth soccer players and nonathletes to test if soccer players display a lateralized performance between their feet. Moreover, motor performance of the feet between youth soccer players and youth nonathletes was compared. The results displayed no significant differences between both groups and within feet for the final position error (FPE). That is, the dominant and nondominant feet had similar accuracy performance in both groups. However, a significant difference was found for foot path deviation from linearity (FPDL). Nonathletes' nondominant foot had worse FPDL compared to dominant foot, which was not observed in soccer players. Thus, whereas nonathletes displayed a lateralized pattern in FPDL, soccer players did not have this pattern in FPDL. The reason to have similar FPE between both groups and within feet may be because all participants focused on the task, which included putting the cursor into the target with their each foot. Although both groups focused similarly to kick the target, soccer players focused on the quality of the kick more (better FPDL) than nonathletes with their both feet. Participating sports activities were found to modify motor lateralization of the arms [17, 28]. That is, the less lateralized motor performance of the arms was observed in different types of sports. In fact, although foot motor performance measurements were taken in the current study, similar findings were obtained.

While there are many studies investigating motor lateralization of the arms in different sports [28, 29], only a few studies focused on foot lateralization in sports. Motor lateralization is essential for successful performance in many sports, which include bimanual tasks (e.g., basketball, water polo, soccer, and volleyball). Less lateralized movements can improve technical skills and thus have positive effects on the game situations. When we consider soccer, it is important to be able to use both feet depending on different game positions [24]. In fact, Haaland and Hoff (2003) [23] found an improved bilateral motor performance of soccer players after 8-week nondominant leg training. In this study, a better motor performance of the nondominant foot in FPDL for the soccer players compared to nonathletes was observed, which is in line with the aforementioned findings. FPDL can be considered to require the coordination pattern of the leg. That is, in order to have better FPDL, leg joints should have good and efficient coordination to perform the kicking task applied in the current study. In this essence, participation of the soccer trainings might improve the lower limb coordination pattern besides other physical fitness parameters.

In modern soccer, players should be able to use their either foot for all technical skills. This could improve the performance of the player, which could help to increase the probability of winning the game. For instance, less lateralized attackers fake the defenders by using their either foot and find opportunities to score a goal [24, 30]. Less lateralized defenders, on the other hand, may be able to tackle the ball away from the defensive zone more quickly and effectively than lateralized attackers [19]. Previous studies have shown that soccer players who can use their both feet showed less lateralized foot behaviors, and thus, they are regarded as a desirable skill at the top-class level and have more successful performance than lateralized soccer players [11, 23–25]. One of the common features of top-class soccer players is that they have applied extensive soccer-specific training to use both feet very well and develop their motor performance level [9, 16, 23]. Therefore, it can be suggested that all coaches working with youth should also include nondominant foot practices in the training program to reduce the level of lateralization.

The soccer coaches should be conscious that players use their both feet during the training sessions. In this case, it may be possible for the soccer players to perform soccer-specific technical skills accurately and efficiently with both feet during the game. It is precisely recommended that coaches should motivate and encourage their players to use both feet. Furthermore, more than 50% of the registered soccer players worldwide were youth athletes [31], thus, it is important to improve their foot motor performance and to teach the players to use both feet at younger ages.

5. Conclusions

Participation of sports activities has many beneficial effects on physical fitness levels. More specifically soccer training was found to improve weight, height, BMI, and standing long jump among the youth [32]. In the current study, it has been also found that soccer training improves the lower limb coordination and decreases the motor lateralization. It might be beneficial to use foot motor performance measurements for the talent identification in soccer in order to get less lateralized players at the initial stage. In this current study, the soccer players who participated in this study were not selected by their soccer clubs with the measurements of their motor lateralization profiles. Thus, the better performance in lower limb coordination observed in the study might stem from the participation of soccer trainings. Future studies may focus on the longitudinal measurements of the motor lateralization to track the changes throughout the times.

Data Availability

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by Institutional Review Board of the Nevsehir Haci Bektas Veli University (permit no: 2018.10.110).

Conflicts of Interest

The author reports no conflict of interest.

Acknowledgments

The author gives special thanks to Dr. B. Okan Micoogullari and Ozkan Beyaz for their help during the data collection process. Special thanks also to Dr. Mehmet Uygur for his valuable comments to the manuscript.

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Hindawi
BioMed Research International
Volume 2022, Article ID 5068599, 9 pages
https://doi.org/10.1155/2022/5068599

Research Article

Effects of 8-Week Orienteering Training on Physical Fitness Parameters among Adolescents Aged 14–18 Years

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Received 3 February 2022; Revised 28 February 2022; Accepted 4 March 2022; Published 17 March 2022

Academic Editor: Stevo Popovic

The aim of this study is to examine the effects of 8-week orienteering training on physical fitness parameters in adolescents. To reveal this effect, this experimental study was designed as a pretest–posttest control group model. A total of 41 volunteers (20 females and 21 males) aged 14–18 years were divided into 2 groups: the orienteering training group (OTG) and control group (CG). Health-related and performance-related parameters of the physical fitness of the participants before and after the 8-week orienteering training were evaluated. After eight weeks of training, body weight (BW) increased by 1 kg on average in the OTG, but the body fat percentage (BFP) did not change. This increase could be due to the effect of the orienteering training. The CG, on the contrary, recorded an increase in BFP. Whereas both groups seemed similar in terms of elastic strength, and a significant improvement was found in the OTG in terms of anaerobic power, which considers BW. In terms of balance performance, the OTG showed a significant improvement, while the CG displayed a 97% rate of negative change. The positive increase rate in aerobic capacity was significantly higher in the OTG compared with the CG. Each participant in the OTG covered approximately 2000 meters engaging in parkour in each training session. Thus, the increase in aerobic capacity for the OTG can be explained by the number of 8-week training sessions. Rockport time decreased statistically in the OTG after training, but there was no difference in comparison with the CG. Moreover, similar results were observed in both the groups in body mass index, flexibility, agility, speed, and VO_{2max} values. Overall, orienteering training once a week for eight weeks resulted in positive developments in physical fitness parameters.

1. Introduction

Regular physical activity contributes positively to human health. However, with technology beginning to play an increasingly bigger role in daily life, individuals spend most of their time on computers, televisions, phones, tablets, video games, etc., which leads to a sedentary lifestyle without sufficient physical activity. Individuals who succumb to a sedentary lifestyle are faced with obesity, hypertension, diabetes, joint disorders, and cardiovascular and respiratory disorders. Further, psychological issues can also occur due to unhealthy food and unbalanced nutrition, stress, and anxiety. Those who indulge in regular physical activity are more energetic, able to perform daily activities without any problems, less prone to falling sick, and generally happier and healthier than those who do not. Physical fitness is defined as the ability to complete daily tasks comfortably and energetically without getting easily tired. Besides, it refers to having the energy to participate in leisure activities and respond to emergencies. Cardiovascular endurance, muscle strength, body composition, flexibility, speed, agility, coordination, and balance are considered components of physical fitness.

These components can be improved through regular physical activity [1–3].

Children and adolescents spend most of their time in school, where they are physically and mentally more mobile and active than in the home environment. Accordingly, it can be concluded that schools are the most appropriate setting to teach students about physical fitness, how it can be improved, and the benefits of improving it. The general objective of physical fitness training is to provide students with the knowledge, skills, attitude, and behavior necessary for them to continue improving their physical fitness levels not only during school years but throughout their life, thereby minimizing the risk of health problems due to insufficient physical activity [4]. Physical activities for children and adolescents should not only be aimed at improving sports performance and success but also physiological and psychological health.

Orienteering, which has been gaining popularity day by day, is a physical activity suitable for all age groups that involves interaction between nature, sports, and humans. In physical fitness, mental strength plays an important role. Therefore, orienteering is also referred to as "running chess" [5]. Orienteering was initially regarded as an outdoor sport; however, with time, it has evolved into a favorable focus of nature, urban, and cultural tourism as a leisure-time activity. It has become a competitive sport, and orienteering championships are being organized. Orienteering can be performed outdoors, encompassing sportive performance parameters, such as speed, balance, reaction time, coordination, aerobic–anaerobic power, and strength, and it helps individuals' physical, mental, and social development [6]. These parameters improve quality of life, ensure healthy living, and increase the sports performance of individuals.

The increased usage of technology has resulted in a sedentary lifestyle for all age groups. The World Health Organization (WHO), along with many countries, is working to improve physical fitness levels of children and adolescents to prevent problems caused by a sedentary lifestyle. Activities such as orienteering that are performed in big outdoor spaces and different terrain types can be used to measure physical fitness levels more objectively. Although orienteering is a distinct sport as it is highly demanding in terms of cognitive and physical skills, it has received little attention in sports literature.

Upon examining recent literature on orienteering, it is seen that studies focus on factors such as problem-solving, visual reaction, and mental processes [7–9]. On the contrary, performance-related studies appear to be limited.

The present study was carried out to examine the effects of an 8-week orienteering training program on the physical fitness parameters among young people aged 14–18 years.

2. Materials and Methods

2.1. Participants. The number of participants in this study is 41, of which 20 are female and 21 are male high school students who participated voluntarily. While selecting participants for the research, the following criteria were considered: the participants should be healthy and not active in any sports. Necessary clarifications were made, and signed written consent was obtained. While outside the school, participants' parents managed their schedule (routine feeding habits, not participating in sports activities, etc.), and at school, teachers managed the program on not participating in physical activities. Participants were randomly divided into two groups, namely, the orienteering training group (OTG), consisting of nine females (16.22 ± 0.83 years) and eleven males (15.91 ± 1.22 years), and the control group (CG) consisting of ten females (16.80 ± 0.79 years) and eleven males (16.09 ± 1.04 years). All the participants completed the research process in full.

The participants in the OTG followed an orienteering training program, which included activities to improve orienteering knowledge and skills as well as relevant motor skills, once every weekend for 8 weeks; the sessions were 45–60 minutes long. The participants in the CG did not follow a training program. The main reason the orienteering training was done once a week was that the participants were preparing for their school exams and university entrance exams; they had limited free time. Therefore, participants' parents did not want their children to spend too much time on sports and physical activities. Yet, with planned and regular orienteering training once a week, the effects of such training on physical fitness parameters were measured.

2.2. Orienteering Training. The orienteering training sessions were conducted in a large campus-like space with slopes and smooth roads, a topographic map of which was drawn in the Antakya district of Hatay province. Throughout the track built in this area, 10 targets were placed randomly at approximately 100-meter intervals. Two points were designated to serve as the starting and finishing points. At the starting point, each participant was given a map showing the locations of the targets and was asked to reach the targets in a particular order as quickly as possible. The participants left the starting point at one-minute intervals. To check whether the participants completed the activity correctly, orienteering control punches were used on the map to mark the relevant points. At the finishing point, participants who had reached all 10 targets submitted their maps to the researcher. For each training exercise, different points on the map were marked as targets, and the participants were asked to decide on their own routes. The distance participants ran in their self-determined routes was measured. These activities were conducted with the OTG in a randomized manner each week at the specified location. The training sessions lasted between 45 and 60 minutes, including the warm-up and rest periods. Specifically, warm-up activities (hopping, jumping, arm swinging, etc.) took 8-10 minutes, stretching exercises (whole body) took 5-8 minutes, and the orienteering training session (reading the map and using the compass while walking, jogging, and running) took 40-45 minutes.

2.3. Procedures. This study adopted a pretest–posttest CG design. Health-related—body weight (BW), body fat percentage (BFP), body mass index (BMI), flexibility, elastic strength, VO_{2max}, and aerobic capacity and performance-related—speed, agility, balance, coordination, and anaerobic power measurements were taken for participants before and after the 8-week orienteering training. Measurements were taken three days before the start of the study and three days after the end of the study. All tests were performed by expert researchers and assistants. Support was obtained from an expert female researcher to determine the skinfold thickness of female participants.

The BW (±0.1 kg) and height (±0.1 cm) of the participants were measured using a portable stadiometer (SECA, UK) while they were in standard sportswear and not wearing shoes. BMI (kg/m^2) was calculated by dividing BW in kilograms by the square of height in meters. A manual skinfold caliper (Holtain, UK) was used to measure the BFP by determining skinfold thickness. Measurements were made from the chest, abdominal, and thigh areas of the male participants and the suprailiac, triceps, and thigh areas of the female participants. BFP was calculated using the body density and BFP formulas introduced by Jackson and Pollock [10].

The flexibility of the participants was determined by the sit-and-reach test. Participants were asked to touch the test bench with bare feet and wait for at least two seconds at the farthest point they could reach without bending their knees. The test was repeated twice and the best value was recorded in cm [11].

Elastic strength was measured with the counter movement jump using a jump meter tool (Seven, Turkey). The participants performed a maximal vertical jump on the jump mat and stood in the half-squat position after the jump without taking their hands off their waist. Participants were given two attempts after a trial jump, and the highest value was recorded in cm [12].

The VO_{2max} values of the participants were determined by performing the Rockport Gait Test. In this test, the participants were asked to walk on a one-mile-long (1,609 m) circular track as fast as they could. Participants' heart rate was monitored with a telemetric device. The finishing times were recorded as well. The participants' VO_{2max} values were calculated using the following formula, which included BW (lb), age (years), gendermale = 1, female = 0), one-mile-run completion time (minutes), and postexercise heart rate (beats/minute): estimated VO_{2max} ($ml.kg^{-1}.min^{-1}$) = 132.853 − 0.0769 × (Weight) − 0.3877 × (Age) + 6.315 × (Gender) − 3.2649 × (Time) − 0.1565 × (HR) [13].

The Yo-Yo Intermittent Recovery Test Level 1 was performed to determine the aerobic capacity of the participants. During this test, the participants were asked to perform 2 × 20 m runs, repeated at increasing speeds, with 10-second periods of active recovery [14]. The test started at the speed of 10 km/h and increased by 0.5 km/h at each level [15]. The tempo was monitored using an automatic acoustic device measuring the values at the start, during the return, and in the end. Aerobic capacity is defined as the maximum distance (m) traveled in cases where a participant fails twice to reach the finish line on time due to fatigue or interruption [14].

The speed levels of the participants were measured using the 30-meter sprint test, their agility levels using the Illinois agility test, their balance levels using the Flamingo Balance test, their coordination levels using the *t*-test, and their anaerobic capacity using the vertical jump test.

The elongated start method was adopted in the 30-meter sprint test. An electronic stopwatch (photocell) with a 0.01-second error margin was placed at the start and end points. All participants started the sprint from 50 cm behind the starting line when they felt ready. Each participant was given two attempts, and the best time was recorded in terms of seconds.

For the Illinois agility test, a 5-m wide and 10-m long track was prepared at the center of which four cones were placed at 3.3 m intervals. The test consisted of a 40-m straight and 20-m slalom run between the cones, with a 180° turn every 10 m. A two-door photocell electronic stopwatch with an error margin of 0.01 seconds was used to record the start and end times. In the test rounds, participants were given three attempts at a slow pace; then, the test was repeated twice and the best score was recorded in terms of seconds [16–19].

In the Flamingo Balance test, a metal beam 50 cm in length, 4 cm in height, and 3 cm in width was used. In this test, the participants were asked to stand barefoot on the beam for as long as possible in a flamingo-like pose. Which leg to stand on was decided by the participants. After starting, the timer was stopped each time the balance was disturbed and restarted when the balance was regained. Balance losses within a minute were counted, and if a participant lost balance more than 15 times in the first 30 seconds, the test was terminated and a score of 0 was given [20].

In the *t*-test, four funnels were arranged in a T shape. A distance of 4.57 m was left between the 3 funnels forming the upper line of the T shape. A funnel, which was set as the starting/finishing point and where a single-channel electronic stopwatch was placed, was placed at the bottom of the T shape, and the distance of this funnel to the funnel in the middle of the upper line was set to be 9.14 m. After the start command, the participants ran toward the funnel in the middle of the upper line and touched it and then continued by taking side steps toward the funnels placed on the sides and touched each funnel with their hands. The test was terminated by running back from the funnel in the middle of the upper line to the starting point [19, 21].

The anaerobic power of the participants was determined by using the values obtained from the vertical jump test in the Lewis formula ($P = \sqrt{4.9} \times (\text{Weight}) \times \sqrt{D}$) [22].

2.4. Data Analysis. The IBM SPSS 23.0 (Statistical Package for Social Science) package software was used for the statistical analysis, and the arithmetic means, standard deviations, mean rank, and sum of ranks were calculated. The obtained data were tested for normality to use parametric statistical analysis. However, as the normality assumption did not meet the criteria to conduct two-way mixed model repeated measures ANOVA, we used the nonparametric equivalent tests. The Wilcoxon signed-rank test was performed for the intragroup comparison of participants' measurement results before and after the 8-week training, and the Mann–Whitney *U* test was performed to compare the pretest and

Table 1: Comparison of the BW (kg), BFP (%), and BMI (kg/m^2) values within and between groups.

		Pretest M ± SS	Posttest M ± SS	Mean rank N/P/T	Sum of ranks N/P/T	z	p
BW	OTG	59.44 ± 11.79	60.59 ± 12.20	7.88/11.16/-	31.50/178.50/-	−2.745	0.006∗
	CG	56.13 ± 13.28	56.65 ± 13.20	9.71/11.64/-	68.00/163.00/-	−1.652	0.099
	U	175.00	163.50				
	p	0.361	0.225				
BFP	OTG	18.66 ± 9.15	18.75 ± 9.08	10.00/11.11/-	110.00/100.00/-	−0.187	0.852
	CG	15.20 ± 7.26	15.78 ± 7.21	8.33/12.07/-	50.00/181.00/-	−2.277	0.023∗
	U	160.00	163.00				
	p	0.192	0.220				
BMI	OTG	20.95 ± 3.21	20.88 ± 3.17	12.10/8.90/-	121.00/89.00/-	−0.597	0.550
	CG	19.47 ± 2.62	19.24 ± 2.63	12.92/8.44/-	155.00/76.00/-	−1.373	0.170
	U	166.00	151.00				
	p	0.251	0.124				

posttest scores of the participants in the respective groups. As a result of these tests, the statistical significance level was found to be $p < 0.05$.

3. Results

Table 1 shows the changes in BW, BFP, and BMI after the 8-week orienteering training and the comparison of these parameters within and between groups.

U: Mann–Whitney U; ∗: $p < 0.05$; M: mean; SS: standard deviation; N/P/T: negative/positive/ties.

In the OTG, a statistically significant difference was found between the pretest and posttest results of the participants in terms of BW, whereas no changes were observed in terms of BFP after the 8-week period. On the contrary, although no change occurred in terms of the BW of the participants in the CG at the end of 8 weeks, a statistically significant increase of 3.81% was observed in the BFP (Table 1). Finally, no statistically significant difference was found in BMI values both within and between groups.

Participants in both groups showed improvement in terms of flexibility over the 8-week period. On the contrary, although no statistically significant difference was found between the groups, it is worth mentioning that the OTG participants' flexibility improved more than those in the CG. Participants in the OTG and CG were found to be at similar levels in terms of elastic strength.

Table 2 shows that the VO_{2max} values of the participants in both groups increased from the pretest to the posttest. Improvement was greater in the OTG (10.39%). A similar situation can be observed in aerobic capacity. Taking into consideration the distances covered in the Yo-Yo test, it was determined that the rate of improvement of the participants in the CG at the end of 8 weeks was 18.75%, whereas that of those in the OTG was 50.88% ($p < 0.05$).

Although there was no statistically significant difference between the groups in terms of the completion time of the Rockport test, the completion time of the participants in the CG did not change from the pretest to the posttest, whereas the completion time of those in the OTG decreased significantly (Table 2).

In both groups, a statistically significant change was observed in terms of speed and agility from the pretest to posttest ($p < 0.05$). When the speed and agility performances of the groups were compared, it was found that the participants in the OTG showed more improvement (Table 3).

The number of failed attempts of the participants in the OTG during the Flamingo Balance test decreased from the pretest to the posttest, whereas the contrary was observed in the CG with a 97% increase in the number of failed attempts. When the posttest results of the groups were compared, the number of failed attempts of the participants in the CG was found to be significantly higher than those in the OTG ($p < 0.05$).

The OTG participants' coordination time significantly reduced at the end of the 8-week training ($p < 0.05$). No significant change was observed in the CG in terms of coordination.

Anaerobic power levels of the participants in the OTG significantly increased from the pretest to the posttest. On the contrary, no statistically significant difference was observed in the anaerobic power levels of the participants in the CG after the 8-week period.

4. Discussion

It has been found that in the 8-week period, improvement was observed only in the OTG in terms of BW, Rockport test completion time, coordination, and anaerobic power, and deterioration was observed only in the CG in terms of BMI and balance. The groups were found to be similar in terms of BMI and elastic strength. However, although a significant change was observed within both groups from the pretest to posttest in terms of flexibility, $VO_{2\ max}$, speed, and agility, no significant difference was found between the groups. On the contrary, a significant improvement was observed in the OTG participants in terms of aerobic capacity, which was also significantly more than that of the CG.

Table 2: Comparison of health-related parameters of physical fitness within and between groups.

		Pretest M ± SS	Posttest M ± SS	Mean rank N/P/T	Sum of ranks N/P/T	z	p
Flexibility (cm)	OTG	27.10 ± 7.45	33.65 ± 7.63	0.00/10.50/-	0.00/210.00/-	−3.932	0.001∗
	CG	23.33 ± 8.33	29.29 ± 11.40	10.00/11.11/-	20.00/211.00/-	−3.333	0.001∗
	U	162.50	164.00				
	p	0.215	0.230				
Elastic strength (cm)	OTG	27.00 ± 6.02	27.01 ± 6.06	9.22/9.78/2	83.00/88.00/2	−0.109	0.913
	CG	27.46 ± 5.85	27.29 ± 5.93	10.50/11.67/-	126.00/105.00/-	−0.365	0.715
	U	199.50	200.00				
	p	0.784	0.794				
VO_{2max} Ml/kg/min	OTG	52.05 ± 10.04	57.46 ± 6.76	1.00/10.50/1	1.00/189.00/1	−3.783	0.001∗
	CG	54.06 ± 7.61	57.62 ± 8.34	3.75/12.71/-	15.00/216.00/-	−3.493	0.001∗
	U	192.00	439.00				
	p	0.639	0.958				
Rockport time (min)	OTG	14.07 ± 1.90	13.28 ± 1.02	10.25/6.88/1	143.50/27.50/1	−2.527	0.012∗
	CG	13.41 ± 0.93	13.16 ± 1.14	11.31/9.00/1	147.00/63.00/1	−1.568	0.117
	U	183.00	189.50				
	p	0.481	0.786				
Aerobic capacity (m)	OTG	452.00 ± 146.88	682.00 ± 340.52	2.50/9.41/3	2.50/150.50/3	−3.513	0.001∗
	CG	396.19 ± 133.81	470.48 ± 192.63	4.38/9.88/5	17.50/188.50/5	−2.629	0.009∗
	U	159.50	131.50				
	p	0.186	0.040∗				

U: Mann–Whitney U; ∗: $p < 0.05$; M: mean; SS: standard deviation; N/P/T: negative/positive/ties.

Although there was no statistically significant difference between the groups with regard to many of the parameters at the end of the 8-week period, relatively more improvement was observed in the OTG in both health- and performance-related parameters of physical fitness. Although the fact that the orienteering training was conducted once a week can be regarded as a limitation, factors such as exam periods and parental restrictions offer the chance to make evaluations and generalizations under real-life conditions. Accordingly, it was found that orienteering training, even once a week, positively contributes to the physical fitness of adolescents, who may not have enough time to perform such activities frequently.

After the 8-week period, an increase was observed in the BWs of the participants in the OTG, while no change was seen in terms of BFP. In light of this finding, it is believed that the weight gain was caused by an increase in muscle mass. Although the BFP of the participants in the CG increased in a statistically significant manner, no significant difference was found between the groups. A similar situation was observed in terms of BMI values. The mean BMIs of the OTG and CG are ($20.95 \pm 3.21–20.88 \pm 3.17\,kg/m^2$) and ($19.47 \pm 2.62–19.24 \pm 2.63\,kg/m^2$), respectively, both of which fall under the "normal range" category according to the criteria accepted by the WHO. Upon examining the literature, it was seen that orienteering and soccer training practiced by participants in different age groups increased their BW from the pretest to the posttest [23–25]. An increase in BFP values was observed in studies conducted at different times and with different age groups with a focus on different sports (orienteering, skiing, football, and fitness), which was found to be higher in the CGs [26–28]. In different studies that were carried out during the weekly physical education class for 8 weeks [23], with late adolescent, young adult, and adult orienteering athletes [29] and with successful and unsuccessful orienteering athletes [26], no difference was found in terms of BMI values. All these studies support the finding of this study that as a result of orienteering training, BW increases significantly but no difference is noted in the BFP values. Thus, owing to orienteering training sessions that activate metabolic functions, fat is reduced and muscle mass is increased.

Flexibility is affected by factors such as age, psychological state (activity level and motivation), temperature, time of day, training and exercise level, muscle and neurophysiological characteristics (elasticity, muscle tone, and intramuscular and intermuscular coordination), fatigue, and warm-up level [30]. In light of the measurement results, it can be held that no differences were found between the groups because of differences in hormonal, neuromuscular, and physiological factors, as well as the fact that participants are in the period of adolescence and that no flexibility exercises were done in orienteering training sessions due to lack of time.

The participants of this study are high school students. The school attended by the participants is of a low–medium socioeconomic status. Students usually walk to school from

Table 3: Comparison of performance-related parameters of physical fitness within and between groups.

		Pretest M ± SS	Posttest M ± SS	Mean rank N/P/T	Sum of ranks N/P/T	z	p
Speed (sec)	OTG	5.46 ± 0.63	5.20 ± 0.65	10.53/5.50/1	179.00/11.00/1	−3.382	0.001*
	CG	5.40 ± 0.59	5.26 ± 0.61	10.59/10.13/1	169.50/40.50/1	−2.408	0.016*
	U	199.50	197.00				
	p	0.784	0.735				
Agility (sec)	OTG	20.17 ± 1.80	19.10 ± 1.61	10.89/3.00/-	207.00/3.00/-	−3.808	0.001*
	CG	19.76 ± 1.68	19.11 ± 1.36	13.13/5.67/-	197.00/34.00/-	−2.833	0.005*
	U	174.500	205.500				
	p	0.354	0.907				
Balance (number of failed)	OTG	4.60 ± 6.08	3.85 ± 4.55	9.08/5.21/7	54.50/36.50/7	−0.630	0.528
	CG	3.95 ± 5.81	7.81 ± 5.17	7.80/10.15/3	39.00/132.00/3	−2.029	0.042*
	U	195.000	116.000				
	p	0.065	0.012*				
Coordination (sec)	OTG	13.53 ± 1.30	12.97 ± 1.19	10.75/8.25/-	193.50/16.50/-	−3.304	0.001*
	CG	13.34 ± 1.20	13.26 ± 1.34	9.54/12.29/1	124.00/86.00/1	−0.709	0.478
	U	194.500	197.000				
	p	0.686	0.735				
Anaerobic power (kgm/sn)	OTG	132.08 ± 26.10	134.64 ± 27.00	8.00/11.13/-	32.00/178.00/-	−2.725	0.006*
	CG	124.77 ± 29.42	125.91 ± 29.24	9.86/11.57/-	69.00/162.00/-	−1.616	0.106
	U	175.000	164.000				
	p	0.361	0.230				

U: Mann–Whitney U; *: $p < 0.05$; M:mean; SS: standard deviation; N/P/T: negative/positive/ties.

their homes. Thus, students cover a certain distance on foot at a certain speed six days a week. This may be the reason the $VO_{2\ max}$ levels of the participants, who are at similar stages of development, were found to be comparable. It is possible that the improvement in the VO_{2max} levels of the participants in the OTG was more due to the increase in their muscle mass, and therefore, the BW. Studies carried out by Byars et al. [31] and Kim et al. [32] support the findings of our study.

Orienteering is an endurance-driven sport that can be performed in all kinds of terrains and differs from other running-based sports, especially depending on the type of terrain on which the sport is performed [6]. Due to the nature and rules of the sport, athletes determine their own routes by taking into account both the conditions of the terrain and the targets on their maps and race against time. Therefore, strong aerobic and anaerobic endurance is required to perform this sport [33]. Indeed, in a study, it was found that type I features are more common in the vastus lateralis and gastrocnemius mediale muscles of elite orienteering athletes [34]. Relevant studies revealed that the oxygen cost of running in the forest is approximately 25% higher compared to the road and that biomechanical differences, especially the stepping pattern, contribute to this increase [35–37]. In the track prepared for this study, which consists of a mixture of flat and rugged terrains, each participant covered an average distance of 2000 meters in each training session, which lasted 45–60 minutes. Therefore, the aerobic capacities of the participants in the OTG increased by an average of 230 m from the pretest to the posttest after the 8-week training. In support of these findings, there are studies in the literature showing that 6-week narrow pitch training [38] or, similarly, 5-week high intensity interval training or narrow-field game programs helped achieve better Yo-Yo test results [39].

Improvement was observed in terms of speed and agility in both groups, with participants in the OTG improving relatively more than those in the CG, though not in a statistically significant manner. This may be due to the muscle mass increase in the participants in OTG. Dündar defined speed as the physical value of the movement against external resistance that starts with a stimulus and is measured by the duration until the completion of the said movement [40]. In early adolescence and middle adolescence (14–18 years), depending on the mobility of nerve processes, the running speed of an individual reaches its full potential [41]. Agility is a rapid whole-body movement with a change in speed or direction in response to a stimulus [42]. Theoretically, the amount of body fat and the length of body segments can affect the level of agility. Of two athletes with the same BW, the one with higher BFP and less muscle mass needs to produce more force per unit of muscle during deflection and negative and positive acceleration due to high inertia [16, 42].

In terms of balance, a statistically significant change was found to have occurred in the CG. Further, a statistically significant difference was found between the groups in terms of the posttest results. The statistically significant difference between the groups was due to the fact that the participants in the OTG strengthened their balance skills throughout the 8-week training program, whereas the participants in the CG deteriorated in this sense in the same period. It is likely that the 8-week training program in which exercises including track running, jumping over hurdles and bumps, careful movement, and holding a specific pose for balance were done, and the additional muscle mass gained by the participants helped improve their balance skills. It was concluded in similar studies in the literature that such training programs help improve balance [26, 29, 43, 44]. It was found in similar studies carried out with participants from different age groups by performing other sports that balance can be improved with exercise and training [45–49].

From the pretest to the posttest, an improvement was observed in the OTG in terms of time needed for coordination, whereas no change was seen in the CG in that regard. Although a 4.3% improvement was observed within the OTG after the 8-week period, no significant difference was found between the groups. As limbs grow rapidly during puberty, individuals become less capable of using their hands and legs, which leads to the deterioration of their coordination skills [50]. Factors such as height, weight, balance, speed, age, and level of physical condition affect coordination. The fact that the ages of the participants vary between 14 and 18 explains the findings of this study on coordination. Indeed, in the studies of Çınar-Medeni et al. [29] conducted with late adolescent, young adult and adult orienteering athletes and of Padrón-Cabo et al. [51] conducted with adolescent football players in which the effects of coordination exercises performed using an agility ladder on physical fitness and technical performance were investigated, no significant difference was found between the OTG and CG in terms of coordination levels.

In the Lewis formula, which is used to measure the anaerobic power of athletes, both the jump height and BW of the individuals are taken into account. Table 1 shows that the mean bodyweight of the participants in the OTG is higher than that of those in the CG; however, the jump heights were found to be similar (Table 2). The participants in the OTG were able to improve their jump heights although their bodyweights increased, which points to increased anaerobic power. Despite the fact that no change was observed in the CG in this regard, no significant difference was found between the groups. These findings indicate how effective regular physical activity can be. The findings of this study are consistent with similar studies in the literature in terms of the effectiveness of training programs in this age group and similar age groups, as well as of detecting no significant difference between the OTG and CG [52, 53].

5. Conclusions

The participants in the OTG participated in the training sessions regularly, willingly, and happily, and at the end of the study, they gave positive feedback on how this training contributed to their life in terms of socialization and school success. After the study was completed, the participants continued with orienteering training. They participated in interschool orienteering competitions and ranked first and second in the province in three of the four categories.

We should also mention that the orienteering training took 8 weeks and was limited to adolescents. Similar studies with different age groups should be conducted to check if similar findings would be observed.

In conclusion, in a busy schedule comprising school, homework, and private lessons, accommodating an hour of orienteering training in a natural setting once a week will positively contribute to the physical fitness of adolescents.

Data Availability

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

The study was conducted in line with the guidelines of the Declaration of Helsinki and approved by the Hatay Mustafa Kemal University Ethics Committee (2018/166).

Disclosure

The data used in this study were collected in partial fulfillment of the requirements of Özer Türkmen's Master Thesis.

Conflicts of Interest

The authors report no conflicts of interest.

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