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Original Article

Effect of leg length on running speed of sports and health sciences students in Indonesia: A meta-analysis study

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Abstract:
Science advancement in all disciplines, including sports science, is rapidly growing, which requires an upgrade of knowledge of all parties that are involved and active in the world of sports and coaching to improve sports performance. Regarding the development of sports science related to the increase of short distance running (sprint) speed, many studies have been conducted on the factors that increase the running ability, including leg length. The structure and function of the human body allows to understand how the body responds to a stimulus. This study aims to describe the effect of leg length on improving short distance running (sprint) performance through a meta-analysis. The population in this study included documents related to the correlation between leg length and sprint speed. Purposive sampling technique was employed to collect the research sample, in which the sample was determined based on the suitability of the research theme, and the collected sample must meet the following criteria: (1) made by students or lecturers; (2) published from 2010 to 2018; (3) is quantitative research; (4) discusses the relationship or effect of leg length on the sprint speed. The data were acquired by documenting research articles in Indonesia from various sources collected through the Google search engine. The random-effects model was applied for data analysis using the JASP 0.9.1 software. This software was used to calculate the mean aggregate difference and to draw forest plots and publication bias. Rank correlation and regression, Trim and Fill methods, were employed to identify the existence of publication bias, which indicated that there was no publication bias in this meta-analysis. The obtained results showed that there was a significant correlation between the leg length and speed in short distance running with the correlation value (r) = 0.6801. Long legs allow a wider angle of movement within a certain limit in sports such as running. With a wide angle, the maximum speed is obtained. It can be concluded that there is a significant effect between the leg length and speed in short distance running.
Keywords: short distance, extensive, speed, sprint

Introduction

The development of science and technology in the field of sports also affects the improvement in sports achievement from time to time. Sports science is growing rapidly from various disciplines, including coaching, sports nutrition, exercise physiology, biomechanics, sports health, sports education, and so on. Knowledge of the structure and function of the human body makes it possible to understand how the body responds to a stimulus. An analysis shows the relationships of body anatomy and structure between organs and their functions (Nieuwenhuis et al., 2011). Research in the field of sports achievement has analyzed aspects that can affect the improvement of sports achievement.

High achievement in athletics also needs to be realized and analyzed in-depth based on the results of research. Athletics is mother of sports, that has several numbers such as running, throwing, and jumping; this is an interesting aspect to study. The running numbers that are competed in athletics, both nationally and internationally, consist of sprinting, middle-distance running, long-distance running, relay running, and marathon running (Sears, 2015).

This study focused on the short distance running or sprinting. As a characteristic of sprinting, this sport is carried out anaerobically in the shortest possible time. In athletics, there are several types of running competitions, namely sprinting, middle-distance running, and long-distance running or marathons. Sprints are carried out by following a track with 100 m, 200 m, and 400 m. The 100 m, 200 m, and 400 m sprints are the dominant sports that require the speed of a runner (Girard et al., 2016).

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Sprint is one type of anaerobic sport that prioritizes speed in its implementation so that the indicator of success is determined by the time reached in a certain distance. To achieve the maximum results in sprints requires good mastery of techniques, such as mastery of starting techniques, running techniques, and techniques across the finish line (Bartolini et al., 2011). To improve the techniques can be started from the growth period. It is a golden period to improve techniques, competences to modulate effort, and attitudes that can accelerate the acceleration phase (Giulia et al., 2017). Techniques that can support the achievement of sprints are certainly closely related to a person's physical condition. It is the main factor in the component of motion in sports so that it makes a major contribution to one's achievement. Without a good physique, of course, you will not be able to produce good movements in any sport (Holfelder & Schott, 2014). These physical conditions include physiological and anatomical conditions. According to Moore (2016), several supporting factors to increase running speed are anatomical factors which include height, leg length, size, width, and weight. The anatomy of the body has an equally significant role in achieving sports achievements. According to Thomas et al. (2016), the roles of posture and body type are also very influential and determine one's sports achievement. Running sports, especially sprinting, is strongly influenced by, and closely related to the shape and condition of a person's feet, in this case, the length of the legs.

Based on the anatomy of the human body, leg consists of several parts, namely the upper leg consisting of the thigh bone (femur) and kneecap (patella), the lower leg consisting of the shin bone (tibia), calf bone (fibula), and jumping bone (talus), ankle bones (tarsus), foot bones (metatarsal), and toes (Al-Dirini et al., 2016). The feet also have several locomotor systems, including the muscular, nervous, and skeletal systems. Movements that occur in the lower limbs (inferior extremities) when running or walking can be in the form of flexion, extension, abduction, adduction, and other movements (Svoboda et al., 2016). Based on the point of view of kinesiology and biomechanics and the laws of physics, leg length will greatly affect the stride length so that it affects the distance and the achievement of speed when running. This is in line with the definition of speed; it can be interpreted as the ability to perform movements in a certain time unit, which is determined by body flexibility, nervous system processes, and muscle abilities (Fukaya et al., 2020).

Various studies have often been carried out to improve performance in athletic sports, especially sprinting, but information from previous research results regarding anatomical factors that contribute to running speed is still limited. Therefore, it is necessary to research to find out more focus on how big the contribution of anatomical factors in the form of leg length to sprint speed is. In addition to the technical factors, non-technical factors will certainly contribute to the achievement of sprint speed such as leg length. From the study conducted, it is expected that it can help coaches to determine talented athletes who will then be coached. So far, sprint coaches in Indonesia have not paid attention to the leg length factor, which is estimated to support sprint speed. Based on this, the authors were interested in revealing the contribution of leg length to the sprint speed by analyzing various previous studies. Based on the problems stated above, the research questions from this meta-analysis were whether all the research results in this sample produce or indicate a relationship between leg length and running speed? Based on the results of the meta-analysis, do all the research results sampled contain biased publications? This meta-analysis study focused on the results of research conducted by students or lecturers in Indonesia regarding the relationship between leg length and running speed.

Material & methods

General Background

This study used a correlation meta-analysis design by calculating the effect size of the random effect model. Meta-analysis is a systematic synthesis of various kinds of research on certain research topics and collects relevant research (Cooper et al., 2019). In simple terms, it can be interpreted as an analysis of analysis. As research, meta-analysis is a study of several research results in similar problems and is used to conclude statistically in the hope of completing the data and comparing the data that has been previously found.

Instruments and Procedures

The data collection technique was documentation by collecting existing similar studies. The documents in this research were as journal articles, research reports, theses in the form of paper printed manuscripts or from online media in universities, especially those having a Sports Study Program or the Faculty of Sports Science or Health Sciences in Indonesia. The population in this study was all documents regarding the research on the relationship between leg length and sprint speed.

The research sample was taken using the purposive sampling technique; the sample was determined based on the conformity with the theme of this research and had to meet the following criteria: (1) made by students or lecturers; (2) published from 2010 to 2021; (3) using a quantitative approach; (4) discussing the relationship or effect of leg length on the sprint speed. Of the 104 documents with the same research problems and results collected, 24 documents met the criteria to be the sample and others did not due to the lack of information such as no explanation of the number of samples, wrong method used, and no r-value. The determination of the sample used in this study is briefly described in Figure 1 below.

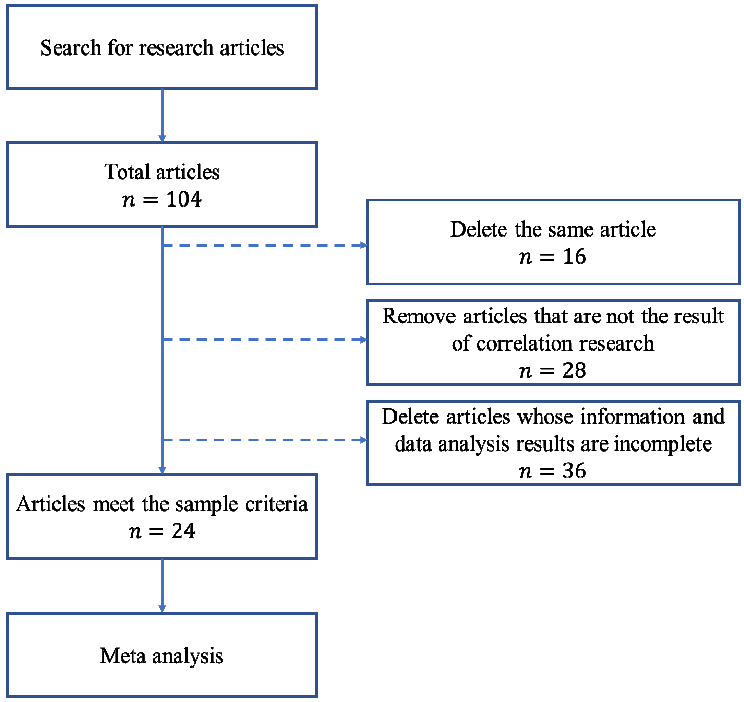

Fig. 1. Schematic of Determining the Number of Samples

Data Analysis Technique

The quantitative data analysis with Excel and JASP programs were employed to determine the effect size of each study or the effect size as a whole and its aggregates. In general, the data analysis process can be explained in Figure 2 below.

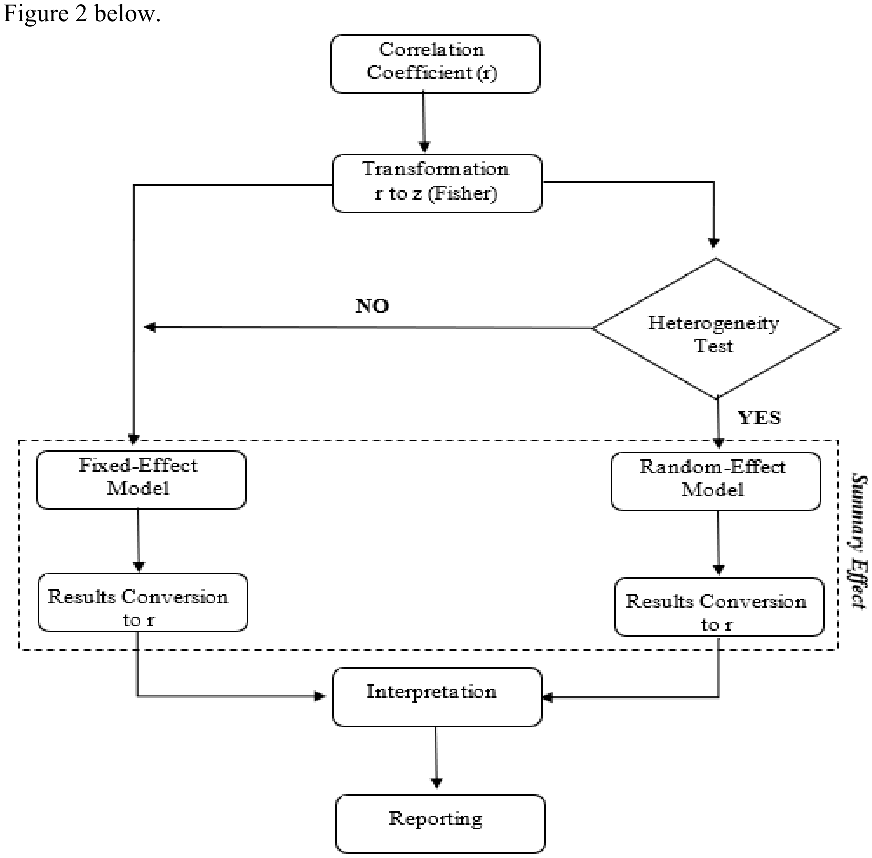

Fig. 2. Schematic of Correlation Meta-Analysis

Results

The study aimed to determine the correlation test of the legs (lower) with the speed of sprinting. Based on the research on 24 studies, the data can be generated as in Table 1 below.

Table 1. Data tabulation of the random-effects model

No.	Studies	r	N	Y (ES)	Vy (SE)	T^2	$Vy+T^2$	W	WY
1.	Purwanto, 2017	0.599	30	0.691	0.192	0.390	0.582	2.343	1.619
2.	Hijir, 2017	0.756	11	0.987	0.354	0.390	0.744	1.942	1.917
3.	Pradana, 2013	0.834	20	1.201	0.243	0.390	0.633	2.229	2.677
4.	Hairunnisha, et al., 2019	0.637	30	0.753	0.192	0.390	0.582	2.343	1.764
5.	Yani & Hasri, 2020	0.923	143	1.609	0.085	0.390	0.475	2.519	4.053
6.	Sorongan, 2014	0.262	40	0.268	0.164	0.390	0.554	2.399	0.644
7.	Amin et al., 2012	0.753	30	0.980	0.192	0.390	0.582	2.343	2.295
8.	Rosti et al., 2020	0.224	35	0.228	0.177	0.390	0.567	2.375	0.541
9.	Sujiono & Marani, 2019	0.411	30	0.437	0.192	0.390	0.582	2.343	1.023
10.	Ad'dien, 2010	0.428	60	0.457	0.132	0.390	0.522	2.455	1.123
11.	Fahrizqi, 2018	0.834	45	1.201	0.154	0.390	0.544	2.418	2.904
12.	Wardimanf & Hermanzoni, 2019	0.590	22	0.678	0.229	0.390	0.619	2.260	1.532
13.	Alsah et al., 2016	0.410	30	0.436	0.192	0.390	0.582	2.343	1.020
14.	Pratomo & Gumantan, 2020	0.707	48	0.881	0.149	0.390	0.539	2.427	2.138
15.	Sihombing, 2019	0.740	30	0.950	0.192	0.390	0.582	2.343	2.227
16.	Jusrianto, 2020	0.532	30	0.593	0.192	0.390	0.582	2.343	1.389
17.	Pinem & Situmeang, 2021	0.72	50	0.908	0.146	0.390	0.536	2.432	2.208
18.	Datang & Pribadi, 2020	0.49	27	0.536	0.204	0.390	0.594	2.318	1.242
19.	Rudianto et al., 2020	0.362	15	0.379	0.289	0.390	0.679	2.113	0.801
20.	Wafiudin et al., 2019	0.642	56	0.762	0.137	0.390	0.527	2.447	1.863
21.	Uket et al., 2017	0.59	17	0.678	0.267	0.390	0.657	2.168	1.469
22.	Mustakim, 2019	0.975	50	2.185	0.146	0.390	0.536	2.432	5.314
23.	Haryanto & Fataha, 2021	0.672	13	0.814	0.316	0.390	0.706	2.042	1.663
24.	Hermawan & Tarsono, 2018	0.775	30	1.033	0.192	0.390	0.582	2.343	2.419
		Total						**95**	**91**

In the analysis using the JASP data processing software, the data required was in the form of effect size (ES) and standard error (SE). In the meta-analysis that reported the value of r (correlation), it was used as the effect size by first being transformed using Fisher's z as shown in Equation (1) below.

$$z \text{ or } Y = 0.5 \times \ln\left(\frac{1+r}{1-r}\right) \quad (1)$$

An example of calculating Y in Study 1 using Equation (1) could calculate the Y value, namely, $Y = 0.5 \times \ln\left(\frac{1+0.599}{1-0.599}\right)$ = 0.691. The calculation of the Y value with the same formula could be carried out in Studies 2 to 25, and the results are as shown in Table 1. Meanwhile, to calculate the standard error (SE) was obtained from the root formula of the z variant with the following equation (2).

Variant of z (V_z) =

$$\frac{1}{n-3} \quad (2)$$

with SE or $V_y = \sqrt{V_z}$ =

$$\sqrt{\frac{1}{n-3}} \quad (3)$$

An example of calculating SE or Vy in Study 1 using Equation (3) could be calculated with values V_y namely, $V_y = \sqrt{\frac{1}{30-3}}$ = 0.129. The calculation of the value of V_y in Studies 2 to 25 using the same formula could be carried out, and the results are as shown in Table 1. Meanwhile, the other data shown in Table 1 was used for manual calculations not using the data processing software.

Summary Effect (Aggregate Effect Size)

The summary effect (aggregate effect size) resulted from 25 studies of the relationship between lower leg length and running speed was noticed based on the coefficient table calculated by the JASP program. From the coefficient table, the summary effect (aggregate effect size) or weighted effect (weighted M) is 0.8293 with a standard error (SEM) = 0.0883 and with a value of z = 9.3955. The complete results are presented in Table 2 below.

Table 2. Summary effect (aggregate effect size)

	Coefficients					
	Estimate	**Standard Error**	**z**	**p**	**Lower Bound**	**Upper Bound**
intercept	0.8293	0.0883	9.3955	< .001	0.6563	1.0023

Note. Wald test

The results of the weighted average effect (weighted M) were also found in the forest plot image with the same value, namely the weighted M value = 0.83 with the lower limit (LLM) = 0.66 and the upper limit (ULM) = 1.00; the confidence interval was at the 95% significance level. The complete results are as in Figure 3 below.

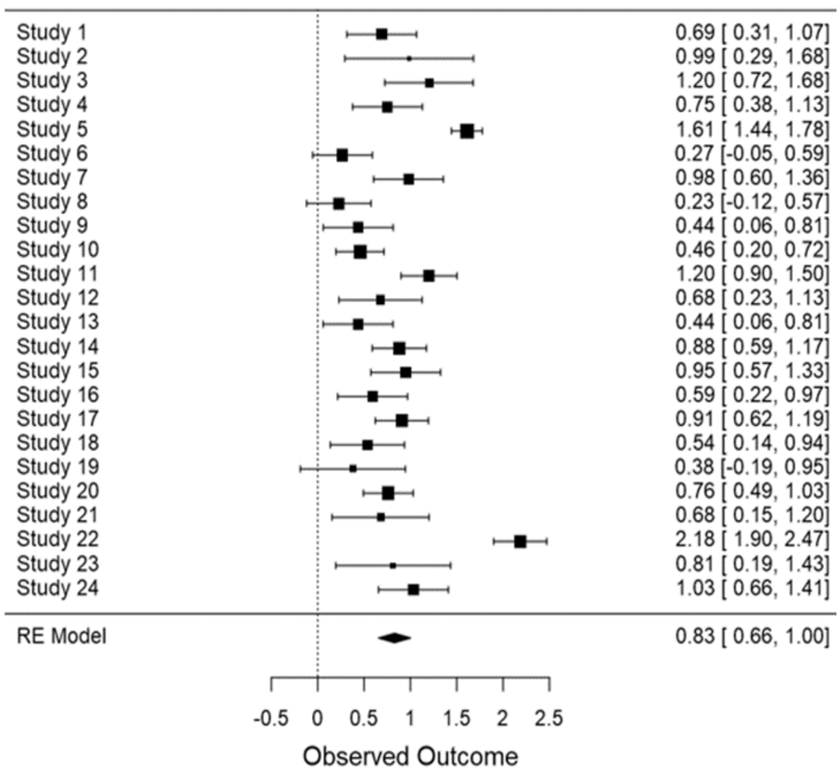

Fig. 3. Forest Plot Summary, Random Effect Model

Correlation Coefficient (Convert the value of M to r) and Heterogeneity Effect Size

The conversion of the weighted average effect size (M) to the correlation coefficient (r) was used to determine the correlation between leg length and running speed. The conversion calculation from M to r and the confidence interval are as follows: $r = \frac{e^{2X0.8293}-1}{e^{2X0.8293}+1} = 0.6801$, $r = \frac{e^{2X0.6563}-1}{e^{2X0.6563}+1} = 0.5759$, and $r = \frac{e^{2X1.0023}-1}{e^{2X1.1.0023}+1} = 0.7626$. Meanwhile, to determine the heterogeneity of the effect size used the tau-square (τ^2) and I^2 parameters; the results are shown in Table 3 below.

Table 3. Residual heterogeneity estimates

	Estimate	**Lower Bound**	**Upper Bound**
τ^2	0.1478	0.0895	0.3477
τ	0.3845	0.2992	0.5896
I^2 (%)	83.1397	74.9137	92.0614
H^2	5.9311	3.9862	12.5967

Based on the calculations as in Table 3, where τ^2 = 0.1478 with a value range of 0.0895-0.3477 and I^2 = 83.14% with a value range of 74.91%-92.06%, the effect size among studies was not the same or heterogeneous.

Publication Bias

Whether the study of the relationship between lower leg length and running speed used in this meta-study indicates publication bias could be seen from various ways. This aspect could be noticed based on the results of the meta-analysis with the JASP program through funnel plot, Rank correlation test for funnel plot asymmetry, and regression test for Funnel plot asymmetry (Egger's test). The funnel plot graph in this study can be shown in Figure 4 below.

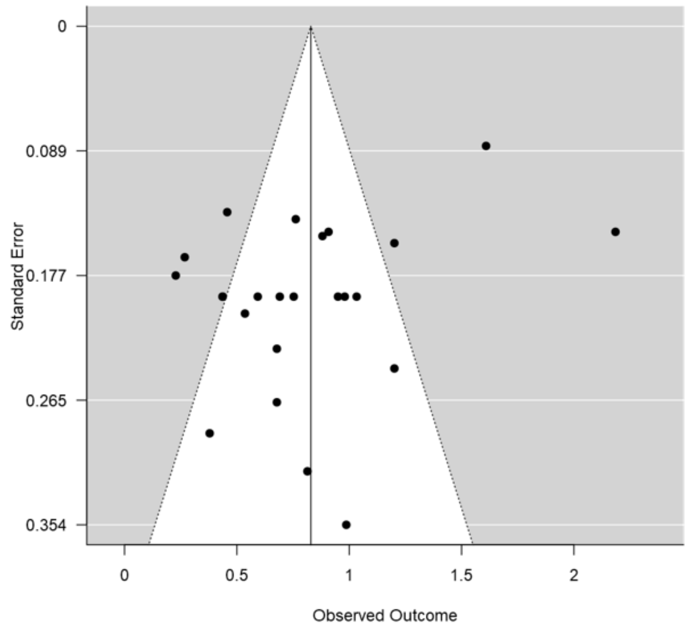

Fig. 4. Funnel plot random effect model

In Figure 4, the funnel plot above shows a relatively symmetrical plot, which means that there is no publication bias. The funnel plot cannot be used as a strong evidence base to claim that the funnel is symmetrical or asymmetrical because the funnel plot is only based on the visual assessment and seems subjective (Zhang et al., 2019). In addition to the funnel plot, publication bias can also be seen from the results of the Rank correlation test for funnel plot asymmetry as in Table 4 below.

Table 4. Rank correlation test for funnel plot asymmetry

	Kendall's τ	**p**
Rank test	0.0191	0.899

Based on the Rank correlations table (Kendall's Column τ), the value of p = 1.0> α = 0.05 was obtained. To sum up, there was no indication of publication bias. Another way to see the publication bias was based on the output produced from the JASP meta-analysis program through the Regression test. Meanwhile, the Funnel plot asymmetry result (Egger's test) is presented in Table 5 below.

Table 5. Regression test for funnel plot asymmetry (Egger's test)

	z	**p**
sei	-1.3064	0.191

Based on Table 5, it is found that the value of p is 0.114> 0.05. It means that there was also no indication of publication bias.

Discussion

Based on the results of data analysis, the research sampled provided a relationship between leg length and sprint running speed. This was evidenced by the calculation results of the correlation r = 0.6801 with p-value = <0.001 in the confidence range of 0.5759 – 0.7626. Leg parts in this study included leg length measured from the hip to the sole or, in anatomical language, measuring the leg length from the anterior superior iliac spine to the medial malleolus. Both parts met the criteria of feasibility: valid and reliable (Brindle et al, 2020). According to Al-Quraish et al. (2018), the walking, running, or others are working movements of the lower limb system (inferior extremity) which involves the bones and muscles that make up the legs, both lower and upper limbs. Long limbs within a certain limit when doing sports such as running will have a wider angle of motion than the other way around. A person's body structure affects every activity in sports because it is usually related to physical ability or strength (Gould et al., 2006). The data used in this study supported the theories and results of research that had been conducted by previous researchers that leg length affected running speed, especially sprints. The results of this meta-study were also in line with those of a study conducted by Baro et al. (2017) on 20 sprint runners aged 17-25 from various universities, who participated in the 2014 Inter College Athletic Meet Dibrugarh University championship; it was concluded that leg strength and leg length provided a positive relationship with running speed. Salamuddn et al., (2014) said that there was a relationship between foot length and stride length frequency, which in turn affected walking speed and efficiency.

The significance of lower leg length for runners to run effectively is most likely due to a more efficient walking stride (Laumets et al., 2017). Meanwhile, shorter legs are consistently weaker in subjects with different leg lengths, and the resulted problem of leg length differences is sufficient evidence of the clinical importance of performing leg length measurements (Monroe et al., 2020). The same findings were also obtained from the results of the meta-analysis study conducted by Seitz et al. (2014) in another country, who concluded that an increase in leg muscle strength contributed positively and significantly to higher sprinting speed. Anthropometric measurements provided useful information for Physical Education teachers/trainers to determine the treatment for students when they were promoted to join sports competitions (Giulia et al., 2017). As for the heterogeneity test, the effect size of the research data was sampled using the Residual Heterogeneity Estimates test with parameters Q^2 and I2; the results obtained were $Q < 0.001$, $^2 = 0.4404$ and I2 = 93.1997 close to 100%. Thus, the effect size between studies was unequal or heterogeneous. Furthermore, to determine the existence of publication bias was based on the calculation results of Rank correlation (Kendal Column, p = 1 > = 0.005), which meant that there was no indication of publication bias.

The anatomical structure of the body plays a role in the achievement of sports, in this case, the length of the legs that can affect the speed of running. In short-distance runners, speed is needed to achieve good results. Thomas et al. (2016) stated that the posture and body type influenced and determined a person's sports achievement. This is in line with the fact that a proportional composition of leg length will be able to determine the exact stride length, stride, and angle that may have an impact on speed. Running sports, especially sprinting, are strongly influenced and closely related to the shape and condition of one's feet, in this case, the length of the legs. Leg length is an independent predictor of energy expenditure. This means that the increase in leg length could provide an effect on decreasing energy expenditure, but would increase walking speed (Salamuddn et al., 2014).

Conclusions

Every part of human body plays an important role in supporting movement activities in sports, including sprinting. One of the human body parts that plays a role in supporting sprinting is legs. Based on the results of research and discussion of this study, legs provided a relationship and affected the speed of sprinting with a correlation value (r) = 0.6801. These results indicated that one of the main factors determining the success of a sprint runner to run fast was influenced by the length of legs. Thus, to obtain optimal results of training or short distance running (sprint) performance, the sprint coach is suggested to not only focusing on the techniques and physical exercises such as strength, explosive power, and so on, but also paying attention to leg length, especially when selecting or monitoring prospective athletes. Based on the results of this study, it is expected that runners and prospective sprint athletes will consider the length of their legs. Researchers and sprint practitioners can also use the findings of this study as an evaluation and reference in optimizing the ability of prospective athletes to increase their sprinting speed.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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