Research Article

Comparison of Kicking Speeds Between Competitive Swimmers with Flat and Normal Feet in Selangor, Malaysia

Anita Yeoh Balakrishnan[1,2], Viswanath Sundar[3], Sharmila Gopala Krishna Pillai[1,4], Sumedha Singh[1,5], Vinodhkumar Ramalingam[1,6*]

1. Department of Physiotherapy, Faculty of Health and Life Science, INTI International University, Bandar Baru Nilai, Malaysia.
2. Department of Physiotherapy, ReGen Rehab Hospital, Selangor, Malaysia.
3. Department of Physical Education & Sport Science, Visva-Bharati University, Santiniketan, India.
4. Department of Physiotherapy, UiTM Cawangan Selangor, Kampus Puncak Alam, Selangor, Malaysia.
5. Department of Physiotherapy, School of Allied Healthcare and Sciences, Jain University, Bengaluru, India.
6. Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences, Chennai, India.

Use your device to scan and read the article online

Citation Balakrishnan AY, Sundar V, Pillai SGK, Singh S, Ramalingam V. Comparison of Kicking Speeds Between Competitive Swimmers with Flat and Normal Feet in Selangor, Malaysia. Journal of Modern Rehabilitation. 2024; 18(1):15-22.

Article info:
Received: April 9, 2022
Accepted: May 11, 2022
Available Online: 01 Jan 2024

Keywords:
Swimming; Flat foot; Medial longitudinal arch; Kicking performance

ABSTRACT

Introduction: Competitive swimming is one of the most popular Olympic sports. Although studies indicate that explored flat feet improved running performance, research on foot types and their impact on swimming is scarce and unexplored. This study investigates the difference between flutter kicking speed among competitive swimmers with flat and standard feet.

Materials and Methods: A total of 78 competitive swimmers in the age range of 13 to 19 years were recruited from Pusat Akuatik Darul Ehsan swimming training using a purposive sampling method and a cross-sectional study design. Based on their navicular drop test scores, the participants were categorized as flat-footed (group A) and normal-footed (group B). An independent t-test was applied to compare the kicking speeds between flat-footed and normal-footed swimmers. The swimmers in group A and group B were instructed to perform a standard 50-m kicking front crawl performance with the upper limb placed over the sliding board individually in a swimming pool, and their reaching time was recorded using a stopwatch.

Results: The results indicated flat-foot swimmers' front crawl kicking performance was faster than normal-foot swimmers' (P=0.03) with a medium effect size (d=0.50).

Conclusion: This study concludes that flat-footed competitive swimmers have an advantage in reaching 50 m in less time than normal-footed swimmers.

*** Corresponding Author:**
Vinodhkumar Ramalingam, Professor.
Address: *Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences, Chennai, India.*
Tel: *+91 (876) 0563032*
E-mail: *vinodh.ramalingam@newinti.edu.my, vino_hai79@yahoo.co.in, vinodhkumar.scpt@saveetha.com*

Introduction

Swimming is a popular physical activity and is considered a part of life skills [1]. Swimming ranks first among the other 10 activities conducted in the spare time of Africa, the United States, the Eastern Mediterranean, Europe, Southeast Asia, and the Western Pacific [2]. In Malaysia, swimming is a relaxing workout. More emphasis is placed on frequency and hours of training in the pool rather than the anatomy and biomechanics of the human body, which significantly affects the swimmers' performance [3]. There are four main competitive strokes: Freestyle, breaststroke, backstroke, and butterfly, and the combination of all these strokes is called the individual medley [4]. A successful swimmer typically spends several years competing in important junior and senior events; however, little data exists on changes in performance over time [5]. A study among Portuguese swimmers reported the proportion of arms and leg work in men's performance was 70.3% and 29.7%, respectively. In comparison, women's performance was 66.6% and 33.4% in a 50 m front crawl sprint. In addition, women use their legs more than men in short-distance swimming [6]. Partial swimming in the pool is part of strength training for the legs using the swim board. In swimming, better swimmers should minimize arm-rowing, focus on the correct kicks, eliminate upper body movements, and place hands close to their bodies underwater. Swimmers with incorrect kicking techniques, such as a kick done only from the knee or a kick with almost straight legs, are forced to engage the core of their body and transfer the entire kick from the hips in the vertical position [7]. A study reported the lower leg's contribution was 37.3%±4.1% in swimming compared with the upper limb's 62.7%±5.1%, highlighting the importance of lower leg strength assessments [8]. In addition, a study showed a significant correlation between 50 m swim and 22.86 m kick time (r=0.790) in front crawl swimming [9].

A study showed that runners with low foot arches are more prone to soft-tissue injuries, whereas runners with high foot arches are more likely to face bony injuries [10]. The longitudinal and transverse arch were worse amongst swimmers than in other competitive sports, such as volleyball and basketball players. Human feet consist of 26 bones with muscles, tendons, and ligaments involved, and they are subdivided into the hind foot, the midfoot, and the forefoot [11]. Metatarsal bones provide stability, while phalanges help stabilize and support the body posture in the stance phase [12]. The height of the foot's medial longitudinal arch (MLA) is another predisposing factor for injuries [10]. The foot types in a clinical setting are identified using MLA as normal feet, low-arched feet, and high-arched feet. From a clinical perspective, MLA is the prominent arch that defines the supination or pronation of the foot [13, 14].

Pronated or low-arched feet are more flexible than normal feet, indicating that lower-arched feet are less stiff and flexible than supinated or high-arched feet [15]. Strength, speed, agility, and balance, however, they vary depending on the type of foot. The study among 14 to 17-year-old female participants reported that flat-footers were significantly better in agility tests, but normal-footers were better in speed and static balance [16]. In contrast, school children aged 11 and 12 with normal arches showed significantly better results in explosive strength on land. In contrast, children with flat feet had considerably better results when performing the speed running test [17]. Similarly, a study investigating explosive strength in younger age groups from 10-20 years showed no significant difference between flat feet and normal feet types [18]. Further, the study reported that the lower arch produced greater muscle strength than the high arch among adults, which may be due to adaptations in supporting the body weight and acting as a shock absorber [19]. Despite research on other variables, such as agility, strength, flexibility, and running speed on different foot types, there is a lack of research on different foot types for swimmers with kicking speed. Thus, this study compares flutter kicking speed among competitive swimmers with flat and normal feet.

Materials and Methods

Study participants

This study was conducted at Pusat Akuatik Darul Ehsan, Shah Alam, Selangor, Malaysia, a training arena for competitive swimmers. A total of 85 male and female participants were enrolled from August 2019 to October 2019 via purposive sampling using a cross-sectional research design. The inclusion criteria were as follows: 1) Swimming competitively for at least four years; 2) Being in the age range of 13 to 19 years; 3) Being healthy with no medical conditions; and 4) Having a navicular drop test (NDT) score confirming both feet having the same foot type. The participants with ongoing lower leg injuries, on medication, or had limb disability were excluded. An information sheet was provided, and informed consent was obtained from all the participants. Parents and coaches provided signed consent for participants under 18 years of age. The participants' swimming career and training involvement were scrutinized from demograph-

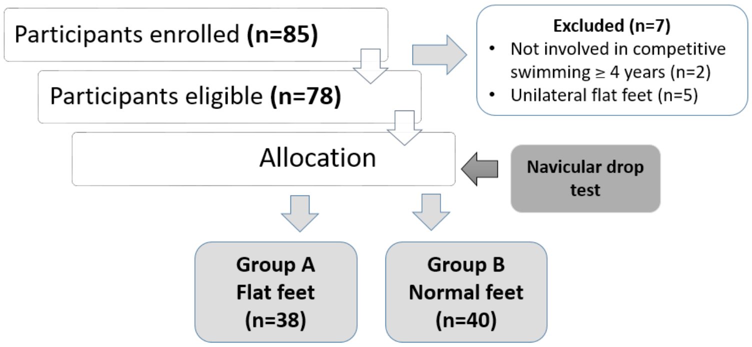


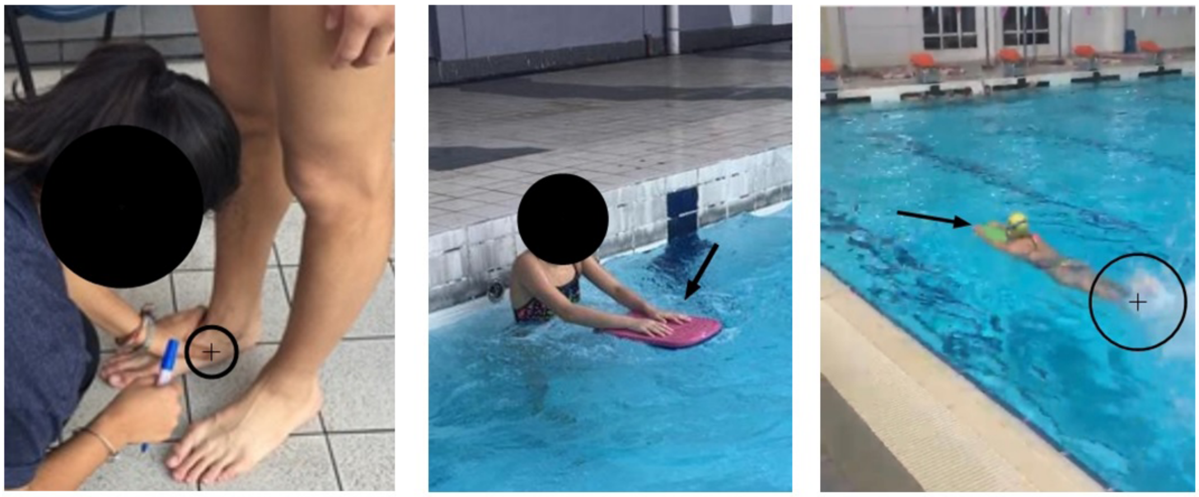
Figure 1. Research flow chart

ic data. The foot type of the participants was assessed by the NDT and categorized as flat foot (group A) and normal foot (group B) based on NDT scores (Figure 1).

Outcome measures

Navicular drop test

The participant's foot type and eligibility were measured using NDT [20, 21]. The reliability of NDT has an intra-class correlation coefficient of 0.83-0.95 [22]. NDT was conducted on both feet as healthy participants stood in an upright standing position with both feet flat on the ground. The relaxed and weight-bearing standing foot assessments represent the displacement of the navicular tuberosity from the neutral foot position in the sagittal plane. The navicular bone was palpated about the medial malleolus to mark the navicular tuberosity. An "x" was drawn over the most prominent aspect of the navicular tuberosity using a marker pen before the measurement. The participants were instructed to bear weight mostly toward the opposite side of the measurement leg but with foot-ground contact (Figure 2a). Then, the talus was returned to a neutral position, and the distance from the navicular tuberosity "x" to the ground was measured as distance 1 (D1) using a measuring tape. A subtalar neutral position was achieved when both the medial and lateral sides of the ankle had an equal talar depression. Next, the participants were instructed to bear equal weight on both feet and repeat the measurement as distance 2 (D2). Each foot was measured three times, and an average measurement was calculated. NDT values were calculated as D1-D2=Dx. The measurements were recorded in mm.



(a) (b) (c)

Figure 2. a) Navicular drop test measurement, b) Starting position for 50 m flutter kick speed test, c) Execution of 50 m flutter kick test with foot action

50 meter flutter kicking test

The 50 m flutter kicking test was conducted for each participant with a foot kick for a distance of 50 m across an Olympic-sized pool using a kicking board that was provided. Each participant was instructed to start the kick test with two hands on the board (Figure 2 b). The pool water temperature was standardized at 27°C to 28°C. Following NDT, the participants' kicking speeds were calculated by recording the time to reach 50 m in the flutter-kicking test. The participants were alone in the pool while conducting the 50 m front crawl flutter-kicking test, with no other swimmers in the lane or surrounding lanes, to reduce drafting and pacing influences, which increase the drag force. A warm-up was provided at the start of the testing session. The test was standardized by providing the kicking board for each participant with instructions to start the kicking test with two hands on the board. The participants were instructed to kick as fast as they could. Cues, such as "take your mark; go!" were given to start the testing (Figure 2c). The time taken for each participant to complete the 50 m freestyle kicking test was recorded using a stopwatch.

Study statistics

The collected data was analyzed using the IBM SPSS statistics software, version 26. The Shapiro-Wilk test established the normality of the collected data, and the data followed the normal distribution where P>0.05. Descriptive statistics was applied for the demographic data, and differences between the groups were analyzed using the independent t-test with P<0.05 as significant. The effect size was calculated using the Cohen d coefficient (0.2="small" effect size, 0.5="medium" effect size, and 0.8="large" effect size) [23, 24]. The sample size was estimated as 84 participants using priori G*Power calculation with an effect size of 0.80, two-tailed α=0.05 to achieve a power of 95% [25].

Results

Among the enrolled competitive swimmers, only 78 participants met the inclusion criteria with the mean age range of 15.26±1.92 years. A total of 7 participants were excluded as presented with unilateral flat feet (n=5) and had not been involved in competitive swimming for more than 4 years (n=2). The participants' demographic data demonstrated that increasing age in group A was observed to have a decrease in the flatfoot appearance among competitive swimmers. Further, the male swimmers had 65.8% flat feet and 52.5% had normal feet, whereas female swimmers had 34.2% flat feet and 47.5% had normal feet (Table 1).

The participants with NDT values ≥10 mm were grouped into flat-foot swimmers (n=38), and the participants with NDT values <10 mm were grouped as normal-foot swimmers (n=40), as shown in Figure 1. The obtained results on the independent t-test indicate that flat-footed swimmers (43.47±5.56 m/s) kick faster than normal-footed swimmers (46.34±5.81 m/s), t (74)=-2.20, P=0.03, d=0.50. Figure 3 depicts a bar graph representing the mean values (s) of the participants' kicking speeds during the 50 m flutter kicking test.

Discussion

This study compared the flutter kicking speed among competitive swimmers with different foot types. The findings based on the independent t-test in the present study demonstrate significant differences in the kicking speed between flat feet and normal feet among competitive swimmers. The demographic data (Table 1) shows that most male swimmers have flat feet compared to female swimmers. Similarly, previous studies reported that male participants were predominantly found to have flat feet, consistent with the current findings [26, 27]. Our data also supports the earlier findings of increasing age

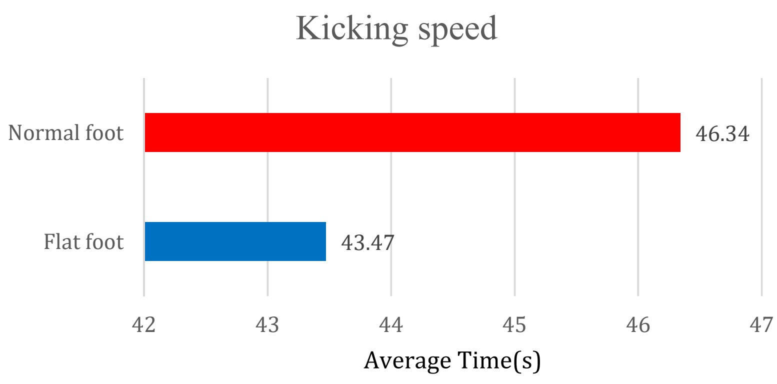


Figure 3. The time taken by participants during 50 m flutter kicking test

Table 1. Demographics characteristics

Variables		Mean±SD/No. (%)	
		Flat Foot (n=40)	Normal Foot (n=38)
Age (y)		15.18±2.01	15.33±1.86
Age (y)	13	11(28.9)	6(15)
	14	6(15.8)	10(25)
	15	6(15.8)	10(25)
	16	5(13.2)	3(7.5)
	17	3(7.9)	5(12.5)
	18	4(10.5)	2(5)
	19	3(7.9)	4(10)
Gender	Male	25(65.80)	21(52.50)
	Female	13(34.20)	19(47.50)
Body mass index	Underweight	6(15.8)	11(27.5)
	Normal	26(68.4)	27(67.5)
	Overweight	3(7.9)	2(5)
	Obese	3(7.9)	-
Swimming frequency	1-2 times/week	-	-
	3-4 times/week	10(26.3)	8(20)
	5-6 times/week	20(52.6)	25(62.5)
	>6 times/week	8(21.1)	7(17.5)
Hours of swimming in a day	<1 h	-	-
	2-3 h	38(100)	40(100)
	4-5 h	-	-
	>6 h	-	-
	Swimming competitively		
	<4 years	-	-
	4-6 years	19(50)	26(65)
	7-9 years	14(36.8)	14(35)
	>10 years	5(13.2)	-
Level of participation	School/Club	-	-
	State	21(55.3)	27(67.5)
	National	11(28.9)	9(22.5)
	International	6(15.8)	4(10)

JMR

with a decrease in the flatfoot appearance [26]. To identify the best swimmers, the flutter kicking test was the common test applied, and in addition, classifying the foot types, such as flat feet, may be the contributory factor of the swimmers' performance [28, 29]. Further, a study among young male swimmers firmly states that biomechanical factors and muscle strength influence the swimmers' crawling speed than the anthropometrical factors [30]. In the current study, swimmers with flat feet require shorter time compared with normal feet because low arch feet or flat feet have advantages in having greater muscle strength, which influences the propulsion speed during flutter kicking in swimming [19, 31]. Studies conducted on runners found that flat-footers have better agility and speed performance than normal-footers [16, 17]. Besides, studies report that ankle flexibility influences kicking speed, which improves swimming performance [9, 32]. Hence, swimmers with flat feet affect the propulsion of flutter kicking speed, which contributes to improved performance. However, the flat foot was further known to increase the risk of injury [10]. Furthermore, the study on flat feet among runners found that they have patella femoral pain syndrome in the knee joint, which may be a disadvantage for swimmers during general physical conditioning [33].

Some methodological limitations in this study should be addressed. The recruited number of participants did not meet the estimated G*Power sample size calculation; therefore, future studies need to be conducted with a larger sample size. Using a stopwatch to assess swimming performance may affect its test accuracy, whereas electronic timing systems should be used in future investigations. Future studies should also investigate the swimmers' flutter kicking rate, lower limb strength, foot size, and various swimming styles and force characteristics. Furthermore, the participants in the flat foot and normal foot groups were not matched in terms of demographic properties, and the level of participation in swimming may have affected the findings in this present study.

Conclusion

The study reported that competitive swimmers with flat feet have an advantage in kicking speed. The authors suggest that the current study would provide information on the advantages of flat feet in kicking speed to physiotherapists, bio-mechanists, and other health professionals involved in foot type evaluation, as well as for the swimming coaches.

Ethical Considerations

Compliance with ethical guidelines

This study obtained ethical approval from the INTI International University Board of Ethics Committee (No.: INTI-IU/FHLS/RAC/BPHTI/JUL/001). All participants read and signed a written informed consent before testing. For participants under the age of 18 years, parents and coaches signed consent forms. The study participants were informed about the purpose of the research and were assured of their information's confidentiality. Moreover, they were allowed to discontinue participation in the study as desired.

Funding

This research did not receive specific grants from public, commercial, or not-for-profit funding agencies.

Authors' contributions

Conceptualization: Viswanath Sundar; Methodology: Vinodhkumar Ramalingam; Investigation, formal analysis and writing-original draft: Anita Yeoh Balakrishnan; Supervision, review and editing: Viswanath Sundar, Sharmila Gopala Krishna Pillai, Sumedha Singh and Vinodhkumar Ramalingam.

Conflict of interest

No financial, legal, or political conflict involving third parties (government, companies, private foundations, etc.) has been declared for any aspect of the work submitted (including, but not limited to, grants and funding, board membership consulting, study design, manuscript preparation, statistical analysis, etc.).

Acknowledgments

The authors would like to convey the gratitude to Pusat Akuatik Darul Ehsan Manager for permitting us to conduct this study and all the participants who had volunteered to participate in this work.

References

[1] Sport England. Towards an active nation. London: Sport Engl; 2016. [Link]

[2] Hulteen RM, Smith JJ, Morgan PJ, Barnett LM, Hallal PC, Colyvas K, et al. Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. Preventive Medicine. 2017; 95:14-25. [DOI:10.1016/j.ypmed.2016.11.027] [PMID]

[3] Aspenes ST, Karlsen T. Exercise-training intervention studies in competitive swimming. Sports Medicine (Auckland, N.Z.). 2012; 42(6):527-43. [DOI:10.2165/11630760-000000000-00000] [PMID]

[4] Del Castillo JA, González-Ravé JM, Perona FH, Del Cerro JS, Pyne DB. The importance of the previous season performance on world-class 200-and 400-m individual medley swimming. Biology of Sport. 2022; 39(1):45-51. [DOI:10.5114/biolsport.2022.103573] [PMID]

[5] Trewin CB, Hopkins WG, Pyne DB. Relationship between world-ranking and Olympic performance of swimmers. Journal of Sports Sciences. 2004; 22(4):339-45. [DOI:10.1080/02640410310001641610] [PMID]

[6] Morouço PG, Marinho DA, Izquierdo M, Neiva H, Marques MC. Relative contribution of arms and legs in 30 s fully tethered front crawl swimming. BioMed Research International. 2015; 2015:563206. [DOI:10.1155/2015/563206] [PMID]

[7] Mason P. Swim better, swim faster. London: Bloomsbury Publishing; 2014. [Link]

[8] Swaine IL, Hunter AM, Carlton KJ, Wiles JD, Coleman D. Reproducibility of limb power outputs and cardiopulmonary responses to exercise using a novel swimming training machine. International Journal of Sports Medicine. 2010; 31(12):854-9. [DOI:10.1055/s-0030-1265175] [PMID]

[9] McCullough AS, Kraemer WJ, Volek JS, Solomon-Hill GF Jr, Hatfield DL, Vingren JL, et al. Factors affecting flutter kicking speed in women who are competitive and recreational swimmers. Journal of Strength and Conditioning Research. 2009; 23(7):2130-6. [DOI:10.1519/JSC.0b013e31819ab977] [PMID]

[10] Williams DS, McClay IS. Measurements used to characterize the foot and the medial longitudinal arch: Reliability and validity. Physical Therapy. 2000; 80(9):864-71. [DOI:10.1093/ptj/80.9.864]

[11] Kolasinski SL, Neogi T, Hochberg MC, Oatis C, Guyatt G, Block J, et al. 2019 American College of Rheumatology/Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip, and knee. Arthritis & Rheumatology. 2020; 72(2):220-33. [DOI:10.1002/art.41142] [PMID]

[12] Bates KT, Collins D, Savage R, McClymont J, Webster E, Pataky TC, et al. The evolution of compliance in the human lateral mid-foot. Proceedings. Biological Sciences. 2013; 280(1769):20131818. [DOI:10.1098/rspb.2013.1818] [PMID]

[13] Parash MTH, Naushaba H, Rahman MA, Shimmi SC. Types of foot arch of adult Bangladeshi male. American Journal of Medical Sciences and Medicine. 2013; 1(4):52-4. [DOI:10.12691/ajmsm-1-4-1]

[14] Knapik JJ, Trone DW, Tchandja J, Jones BH. Injury-reduction effectiveness of prescribing running shoes on the basis of foot arch height: Summary of military investigations.The Journal of Orthopaedic and Sports Physical Therapy. 2014; 44(10):805-12. [DOI:10.2519/jospt.2014.5342] [PMID]

[15] Butler RJ, Davis IS, Hamill J. Interaction of arch type and footwear on running mechanics. The American Journal of Sports Medicine. 2006; 34(12):1998-2005. [DOI:10.1177/0363546506290401] [PMID]

[16] Roohi BN, Hedayati S, Aghayari A. The effect of flexible flat-footedness on selected physical fitness factors in female students aged 14 to 17 years. Journal of Human Sport and Exercise. 2013; 8(3):788-96. [DOI:10.4100/jhse.2013.83.03]

[17] Zivkovic M, Zivkovic D, Bubanj S, Milenkovic S, Karaleic S, Bogdanovic 3. The dependence of explosive strength and speed on feet posture. Journal of Society for development in new net environment in B&H. 2014; 8(2):246-52. [Link]

[18] Petrović M, Obradović B, Golik-Perić D, Bubanj S. Jumping abilities are not related to foot shape. Facta universitatis-series: Physical Education and Sport. 2013; 11(3):299-305. [Link]

[19] Zhao X, Tsujimoto T, Kim B, Tanaka K. Association of arch height with ankle muscle strength and physical performance in adult men. Biology of Sport. 2017; 34(2):119-26. [DOI:10.5114/biolsport.2017.64585] [PMID]

[20] Brody DM. Techniques in the evaluation and treatment of the injured runner. The Orthopedic Clinics of North America. 1982; 13(3):541-58. [DOI:10.1016/S0030-5898(20)30252-2] [PMID]

[21] McPoil TG, Cornwall MW, Medoff L, Vicenzino B, Forsberg K, Hilz D. Arch height change during sit-to-stand: An alternative for the navicular drop test. Journal of Foot and Ankle Research. 2008; 1(1):3. [DOI:10.1186/1757-1146-1-3] [PMID]

[22] Deng J, Joseph R, Wong CK. Reliability and validity of the sit-to-stand navicular drop test: Do static measures of navicular height relate to the dynamic navicular motion during gait. Journal of Student Physical Therapy Research. 2010; 2(1):21-8. [Link]

[23] Cohen J. Statistical power analysis. Current Directions in Psychological Science. 1992; 1(3):98-101. [DOI:10.1111/1467-8721.ep10768783]

[24] Fritz CO, Morris PE, Richler JJ. Effect size estimates: Current use, calculations, and interpretation. Journal of Experimental Psychology. General. 2012; 141(1):2-18. [DOI:10.1037/a0024338] [PMID]

[25] Tomczak M, Tomczak E, Kleka P, Lew R. Using power analysis to estimate appropriate sample size. Trends in Sport Sciences. 2014; 21(4):195-206. [Link]

[26] Pourghasem M, Kamali N, Farsi M, Soltanpour N. Prevalence of flatfoot among school students and its relationship with BMI. Acta Orthopaedica et Traumatologica Turcica. 2016; 50(5):554-7. [DOI:10.1016/j.aott.2016.03.002] [PMID]

[27] Bordin D, De Giorgi G, Mazzocco G, Rigon F. Flat and cavus foot, indexes of obesity and overweight in a population of primary-school children. Minerva Pediatrica. 2001; 53(1):7-13. [PMID]

[28] Strzała M, Stanula A, Krężałek P, Rejdych W, Karpiński J, Maciejczyk M, et al. Specific and holistic predictors of sprint front crawl swimming performance.Journal of Human Kinetics. 2021; 78:197-207. [DOI:10.2478/hukin-2021-0058] [PMID]

[29] Marinho DA, Oliveira R, Garrido ND, Barbosa TM, Costa MJ, Silva AJ, et al. The relationship between front crawl performance and hydrodynamics in young female swimmers. Biomechanics in Sports. 2011; 11 (Suppl. 2):323-6. [Link]

[30] Nasirzade A, Ehsanbakhsh A, Argavani H, Sobhkhiz A, Aliakbari M. Selected anthropometrical, muscular architecture, and biomechanical variables as predictors of 50-m performance of front crawl swimming in young male swimmers. Science & Sports. 2014; 29(5):e75-81. [DOI:10.1016/j.scispo.2013.09.008]

[31] Peter M, Martina M, Romana P. The impact of special strength intervention in water on the flutter kicking performance in swimming. Journal of Physical Education and Sport. 2020; 20(02):774-82. [Link]

[32] Watkins J. The effects of leg action on performance in the sprint front crawl stroke. Biomechanics and Medicine in Swimming. 1983; 310-4. [Link]

[33] Takabayashi T, Edama M, Inai T, Kubo M. Shank and rearfoot coordination and its variability during running in flatfoot. Journal of Biomechanics. 2021; 115:110119. [DOI:10.1016/j.jbiomech.2020.110119] [PMID]