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Review paper

EFFECT OF WARM-UP ON FITNESS PERFORMANCE OF SCHOOLCHILDREN. A SYSTEMATIC REVIEW

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Abstract

Introduction. The impact of different types of warm-up protocol on children's performance is clearly an unresolved issue that has not yet been satisfactorily investigated. Consequently, the purpose of this review was to analyze the current literature on the subject. ***Material and Methods.*** The first step was to perform a search in PROSPERO with the keyword warm up. After that, five electronic bibliographic databases were searched through until April 10th, 2021: Web of Science (all databases), Scopus, SportDiscus, PubMed, and Google Scholar. ***Results.*** Six studies involving a total of 138 participants were included in the final analyses. Regarding the physical qualities that were assessed, 4 of the studies assessed strength through the vertical jump, 3 assessed running speed, one assessed anaerobic endurance (30 seconds) with a cycle ergometer and another assessed flexibility using the Sit & Reach. ***Conclusions.*** The practice of dynamic or specific warm-up before training appears to improve speed and strength performance compared to no warm-up in school-age children. However, the effects of warm-up on endurance and flexibility performance in school-age children need to be further investigated.

Key words: warming up, physical qualities, children's performance

Introduction

Warm-up (WU) is the most common practice before training or any sporting event [1, 2], and it is commonly a part of most physical education (PE) classes at schools [3]. Warming up increases body temperature, coordination, blood flow and psychological preparation [4, 5]. It is also included to improve performance and for protection against injuries [6]. Likewise, it is stated that WU have acute effects on speed, jump, strength or endurance performance [1, 7]. Additionally, there is evidence showing that WU could improve motor competence, motor performance and motor learning [8]. Traditional WU is generally composed of low-to-moderate intensity aerobic activity, stretching and specific exercises [9].

Studies suggest that the performance of the school-age children is better on speed, jump and motor skills when warming up than when WU is not performed [1, 10, 11].

Stretching, as an integral part of WU, is performed to maximize sports performance and prepare the body for training sessions or competition [12]. The stretching effects are a frequent subject of research in sports and PE, but the results are conflicting. Faigenbaum et al. [13] compared WU with dynamic exercises to WU with static stretching and found that static stretching impaired vertical jump performance in adolescent athletes. In contrast, static stretching has no negative effect on the vertical jump of adolescent tennis players [14]. Similarly, other controlled studies in children found that dynamic stretching or dynamic exercises compared with static stretching and no stretching at all, as the final part of WU, improved explosive strength [6, 15]. Moreover, in young female handball players, dynamic stretching improved sprint performance to a greater extent than static stretching and no stretching as the final part of WU [16]. As a result of all the above, there is an active debate as to which stretching technique is best to use in WU and how it should be designed and executed [17, 18].

The impact of different types of WU protocol on children's performance is clearly an unresolved issue that has not yet been satisfactorily investigated [6]. This issue is one that is also of interest to PE teachers, youth sports coaches and sports scientists [18]. Therefore, evidence of effects of WU on fitness performance in schoolchildren is limited [15]. Consequently, the purpose of this review was to analyze the current literature on the subject. Also, it aimed to analyze whether warming up influences school-age children's performance, and to determine the best WU protocol to improve the performance of different basic physical qualities in school-age children.

Material and Methods

The first step was to perform a search in PROSPERO with the keyword warm up. Eighty-four items were found, but none were directly related to our study. Therefore, the systematic review was registered on PROSPERO (Registration number: CRD 42021255659). The following five electronic bibliographic databases were searched through until April 10th, 2021: Web of Science (all databases), Scopus, SportDiscus, PubMed, and Google Scholar. The searches were carried out in the search field type "Title, abstract, and keywords" or equivalent (e.g. "Topic" for the Web of Science database). Any publication format including journal papers, but not grey literature (i.e. master/doctoral dissertations and conference proceedings) was examined. Additionally, no language or publication date restrictions were imposed.

The search terms used were based on two concepts. These concepts included terms related to warm-up (pre activity, preliminary exercises, activation, pretraining, warm-up exercise, preexercise ...) and schoolchildren (childhood, prepubescent, kid, young, preadolescent, school-aged, primary-schooler ...). Additionally, the keywords that consisted of more than one word were enclosed in quotes. Finally, the terms were combi-

ned with the Boolean operator "OR" [19]. Based on the results of the Boolean-based search (as well as all the related studies by Léger), other modes of searching were carried out. The reference lists of all studies were manually searched. Furthermore, the reference citations (in the Web of Science and Scopus databases, and ResearchGate and Google Scholar), the researcher publications of the first authors (in the Web of Science and Scopus databases, and in ResearchGate and Google Scholar), the researcher's personal lists (in ResearchGate and Google Scholar) were also examined, and the correspondence authors were contacted by email.

Inclusion and exclusion criteria

Studies were included if they (1) investigated the effect of warm-up on performance in schoolchildren as the main focus; (2) explored the effect of warm-up on strength, speed, endurance and flexibility; (3) were peer-reviewed journal articles. Studies were excluded if they (1) used not validated tests to assess performance; (2) were grey research literature or (3) were not controlled (no warm-up condition). The risk of bias was assessed by two reviewers. The two reviewers independently screened all study titles and abstracts. The full text of the studies that potentially met the inclusion criteria (based on title and abstract screening) was obtained, and all potentially relevant references were retrieved according to the predefined inclusion criteria. Differences were resolved by discussion or, if necessary, would have been resolved by consultation with a third researcher of the University to reach a consensus. There was no discrepancy between the reviewers when rating the studies.

Results study description

Of the 5,606 bibliographic databases search results, 251 potentially relevant publications were retrieved for a more detailed evaluation (there were 109 studies excluded based on selection criteria and 115 studies removed for being duplicate s). Afterward, based on the studies of the Boolean-based database search, 6 studies were selected. Another 3 additional records were identified through other sources, but all of them were excluded based on selection criteria. Finally, 6 studies met the selection criteria (Fig. 1).

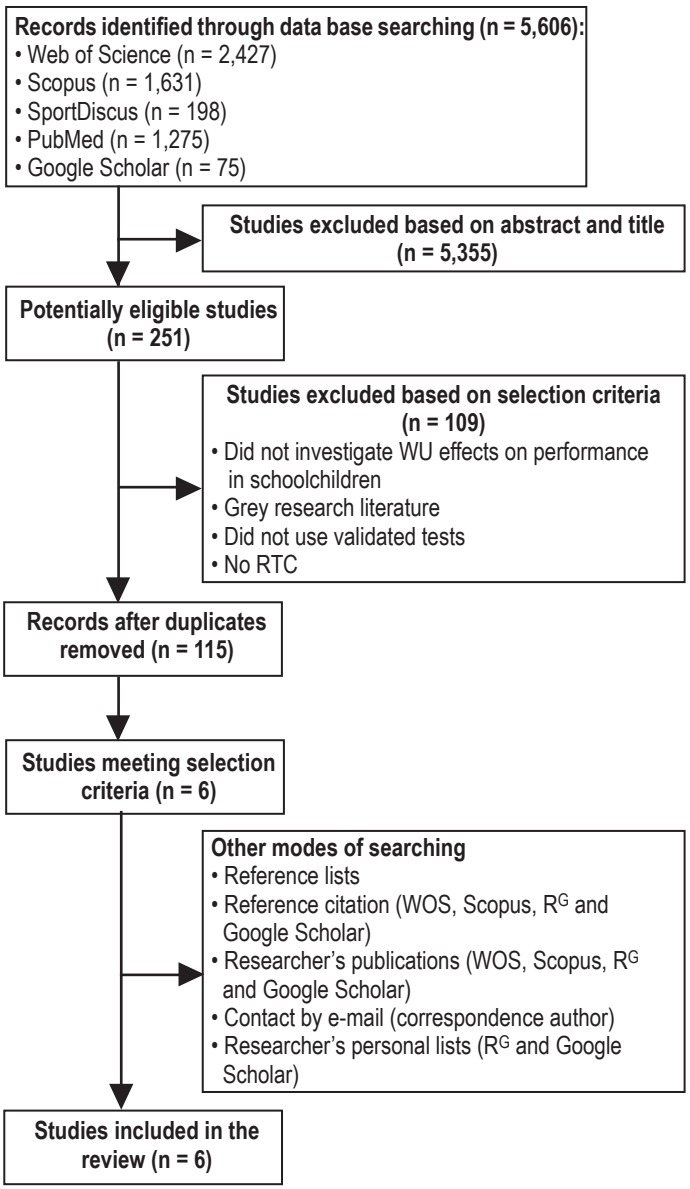

Figure 1. Flow diagram of the systematic review

Results

Six studies involving a total of 138 participants were included in the final analyses. The included studies were conducted in Brazil, Chile, the USA, England, Spain and Turkey. Two studies included only male participants [10, 20], one study included only female participants [21], and three studies included both male and female participants [1, 11, 22]. All participants were school-aged children with a mean age range between 9.33 ± 0.48 years in the study with the youngest sample and 16.48 ± 0.68 years in the study with the oldest sample. The participants included sedentary children [10], healthy children involved in PE lessons [1, 22], volleyball players [21] and two of the studies did not provide information [11, 20]. Regarding the physical qualities that were assessed, 4 of the studies assessed strength through the vertical jump, 3 assessed running speed, one assessed anaerobic endurance (30 seconds) with a cycle ergometer and another assessed flexibility using the Sit & Reach (Tab. 1).

Various sections on the performance of schoolchildren after WU or No WU (NWU) are described below. A heading has been made for each of the fitness qualities that affect fitness performance.

Flexibility

Only one of the studies in this systematic review [22] assessed flexibility through the Sit and Reach (SR) after performing WU and without it. In this investigation, WU protocol does not appear to influence hamstring and low back flexibility. Both WU with static stretching, WU with dynamic exercises and no WU produced the same results in the SR.

Endurance

Howe et al. [20] were the only ones evaluating endurance, and it was anaerobic endurance tested with the Isokinetic Anaerobic Test (IAT). The test consisted of 30-second performance at full intensity on a cycle ergometer. It was noted that WU prior to IAT seemed to result in less La accumulation and to have a positive impact on acid-base status during recovery.

Table 1. General characteristics of the studies and their results

Author	Sample	Warm-ups	Test	Results
Çelik et al. (2021)	N = 30 (12.63 ± 0.89 years)	1.NWU, 2.GWU, 3.PIMWU & 4.IMWU	10 m, 20 m, 30 m & 50 m	2 & 4 ↑* vs 1 & 3
Duncan et al. (2006)	N = 40 (10.15 ± 0.4 years)	1.No WU, 2.SSWU & 3.DWU	SR & CMJ	3 ↑* CMJ 1, 2 & 3 = SR
Gómez-Álvarez et al. (2021)	N = 27 (9.33 ± 0.48 years)	1.NWU, 2.TWU, 3.BGWU & 4.FIFA-11WU	CMJ, 20 m & TGMD-2	2, 3 & 4 ↑*. 3 best in TGMD-2. 4 best in 20 m & CMJ
Howe et al. (1995)	N = 6 (11 ± 0.6 years)	1.NWU, 2.58% VTWU & 115% VTWU	IAT, Blood [La], HCO3 & pH	VTWUs result in less (La) & HCO3
Rezende et al. (2016)	N = 8 (15.4 ± 0.5 years)	1.NWU, 2.SSWU, 3.CWU, 4.REWU & 5.VJWU	CMJ	5 best to ↑CMJ
Ruiz et al. (2020)	N = 27 (16.48 ± 0.68 years)	1.NWU, 2.TWU & 3.SWU	CMJ & 5 m	3 best to ↑* CMJ & 5 m

BGWU: Based on Games Warm-Up; CMJ: Counter Movement Jump; DWU: Dynamic Warm-Up; GWU: General Warm-Up; IAT: Isokinetic Anaerobic Test; IMWU: Inspiratory Muscle Warm-Up; NWU: No Warm-Up; PIMWU: Placebo Inspiratory Muscle Warm-Up; REWU: Resistance Exercise Warm-Up; SR: Sit & Reach; SWU: Specific Warm-Up; SSWU: Static Stretching Warm-Up; TGMD-2: Test Gross Motor Development; TWU: Traditional Warm-Up; VTWU: Ventilatory Threshold Warm-Up; WU: Warm-Up; ↑*: increased performance significantly.

Strength

Gómez-Álvarez et al. [1] determined that FIFA 11+ Kids was the best WU on counter movement jump (CMJ) compared to no WU, traditional WU (joint mobility and aerobic running for 13 minutes) and WU based on games (18 minutes of traditional games). Rezende et al. [21] and Ruiz et al. [11] pointed out that specific WU, compared to no WU, was the best protocol in CMJ test. Duncan et al. [22] found significance differences in CMJ following dynamic WU (10 minutes of 8 dynamic stretching) versus no WU and static WU (5 minutes of walking and 5 minutes of static stretching).

Speed

Çelik et al. [10] evaluated speed through 10 m, 20 m, 30 m and 50 m tests. The results showed that general WU (low-intensity aerobic running for 10 minutes and dynamic stretching for 5 minutes) and inspiratory muscle WU (30 breaths x 2 sets of 40% MIP and 1-minute rest between sets) increased performance significantly compared to no WU and placebo inspiratory muscle WU. Gómez-Álvarez et al. [1] evaluated 20 m sprint test, revealing that WU based on games (18 minutes of traditional games) and FIFA 11+ Kids WU were better than no WU or traditional WU (joint mobility and aerobic running for 13 minutes). Besides that, Ruiz et al. [11] indicated that specific WU was the best to improve performance in 5 m speed test when compared with no WU and traditional WU.

Year of publication

If we look at the year of publication, the articles included in the review, except for one, are quite recent: two from 2021, one from 2020, one from 2016, one from 2006 and the oldest from 1995.

Discussion

The The purpose of the present review was to examine the effects of WU and no WU on fitness performance of school-age children. Overall, the results of the studies included in this review indicate that WU compared to no WU is a performance-enhancing strategy for school-age children. In addition, we wanted to determine the best WU protocol to improve school-age children's performance of different basic physical qualities.

WU vs No WU

There are few studies that compare effects of different protocols of WU and no WU on school-aged children [1, 10, 11, 21]. The search shows that depending on the physical quality to be trained, the protocol may be different. Nevertheless, it seems clear that no WU offers worse results than dynamic or specific WU. An important thing is that WU should be specific to training in order to prepare and activate the muscles and the energy systems that are required for each particular exercise [23].

Flexibility

According to Duncan and Woodfield [22], WU protocol does not appear to influence hamstring and low back flexibility, as both WU with static stretching, WU with dynamic exercises, and no WU produced the same results in the SR in school-children. Nevertheless, numerous studies pointed out that stretching exercises in WU increase the range of motion [3, 24]. Andrejić [25] compared four WU protocols in boys, all of them composed of a 5-minute moderate-intensity jog followed by no stretching, static stretching, dynamic exercises, or dynamic exercises plus 5 drop jumps. The results showed significantly lower SR performance for no stretching compared to the other three protocols. However, no differences were found for flexibility performance between WU protocols with static stretching, dynamic exercises or dynamic exercises plus 5 drops.

In their study, Coledam et al. [3] examined 58 children who performed static stretching during WU of the 2 weekly PE classes over 16 weeks. The children in the intervention group significantly improved their flexibility measured by the SR test, while those in the control group, who warmed up but did not stretch, had no improvement. There is controversy in the effects of WU on flexibility performance, but it seems clear that WU that includes stretching results in better performance in school-age children [3, 24, 25].

Manjre [26] compared active, passive and no WU in collegiate cricket players, showing significant differences in flexibility. They revealed that the best performance was noted after active WU, followed by passive WU. In the same line, Ray et al. [23] showed that collegiate players had the best results in flexibility after performing dynamic or passive WU, while the worst results were found in those who did not do WU.

Therefore, studies seem to indicate that WU improves flexibility compared to no WU. When WU ends with stretching, this improvement is even greater.

Endurance

Using IAT, Howe et al. [20] showed that WU appeared to result in less La accumulation and to have a positive impact on acid-base status during recovery in prepubertal boys than in the case of no WU. Faigenbaum et al. [27] compared the effects of moderate- and high-intensity exercise movements vs low-intensity treadmill walking on maximal treadmill exercise performance in children. They found that after WU with moderate- and high-intensity exercise movements, VO2 peak was higher, including a trend to greater maximal heart rate. In the study on youth soccer players, Needham et al. [28] also noted that including WU with resistance exercise may be beneficial for anaerobic performance. In addition, Zourdos et al. [29] recommended WU vs no WU; however, they did not find significant differences in a 30-min distance trial because there was a positive increase inVO2 and heart rate in male college endurance athletes. On the contrary, in a more recent study, Takizawa et al. [30], who examined trained male athletes (21.3 ± 2.1 years), concluded that 3,000-5,000 m track events were not affected by following or not following WU.

Moreover, focusing on core endurance, Liao et al. [31] claim that the introduction of functional dynamic WU in PE class improves performance in core area muscle endurance test in teenagers. On the contrary, Ray et al. [23] compared the effects of active and passive WU as well as no WU on endurance of core muscle in college students and did not find significant differences.

Therefore, studies on the effects of WU on endurance improvement in school-age children are somewhat controversial.

Strength

Prior to a strength training, Duncan et al. [22] recommended dynamic WU in primary school children, claiming that it leads to better performance in CMJ compared to no WU or static WU.

Gómez-Álvarez et al. [1] observed that FIFA 11+ Kids were the best in CMJ compared to no WU, traditional WU and WU based on games for schoolchildren. On the other hand, both Rezende et al. [21] and Ruiz et al. [11] pointed out that specific WU was the best protocol in CMJ test in children. In the same line, dynamic-bouncing stretching as the final part of WU improved explosive strength (standing long jump test) performance in primary schoolchildren compared to not stretching or doing static stretching as the final part of WU [15].

In the same way but in college football players, Pagaduan et al. [32] studied the effect of different WU strategies on CMJ performance. They concluded that general WU or general WU with dynamic stretching led to the greatest gains among all interventions, and no WU and passive static stretching displayed the lowest results in CMJ. Other studies [23, 26] concluded that collegiate students showed better results in explosive strength after active and passive WU and the lowest performance after no WU.

It is important to add that general WU, inspiratory muscle WU, WU based on games, FIFA 11+ Kids and specific WU seem to improve strength performance in schoolchildren [1, 11, 21, 22].

Therefore, traditional WU ending with dynamic exercises or dynamic stretching seems to be a better option to improve performance in the physical quality of strength in school-age children than no WU at all.

Speed

Çelik et al. [10] showed that general WU and inspiratory muscle WU had significantly greater results in children compared to no WU and placebo inspiratory muscle WU in 10 m, 20 m, 30 m and 50 m tests. Gómez-Álvarez et al. [1] evaluated 20 m sprint test, pointing that WU based on games and FIFA 11+ Kids WU increase performance in schoolchildren compared to no WU or traditional WU. Besides that, Ruiz et al. [11] indicated that specific WU was the best in adolescents to improve performance in 5 m speed test in comparison with no WU and traditional WU. In the same line, Ray et al. [23] concluded that college players showed better results after active WU followed by passive WU, showing the lowest results after no WU. In addition, Manjre [26] stated that after active WU or passive WU, performance is better compared with no WU in collegiate cricket players.

According to Ray et al. [23], WU is more vital for those activities in which quick movements and fast running are involved. It improves performance by increasing the rate and strength of muscle contraction. As with strength, WU before a speed test seems to improve performance compared to no WU. Furthermore, this WU should be specific and/or end with dynamic exercises or dynamic stretching, but not static stretching.

Year of publication

As pointed out by numerous authors, in recent years, there has been an increase in interest and the number of studies trying to know how WU could affect fitness performance [18, 33]. There are a number of controversies about WU as to whether WU really helps in higher levels of performance, or it is only a psychological factor [23].

Although it seems clear that WU improves fitness performance, future research should lead to a more conclusive study that would compare each WU protocol in different basic physical abilities in a bigger sample and several ages, noting if there exists any change along primary years. That way, it would help us to know the most appropriate WU protocol to be used in school-age children.

Practical Applications

Although the results of WU in terms of endurance performance are contradictory, it is advisable to employ WU for the physiological and activation effects it produces. To include dynamic exercises, dynamic stretching and specific WU before training strength or speed seems to improve fitness performance of schoolchildren. Despite Duncan and Woodfield's [22] results, current scientific evidence suggests that WU improves flexibility in school-age children compared to no WU. This knowledge would help and guide PE teachers' actions to develop better PE lessons and get the best results from their pupils.

Conclusions

The practice of dynamic or specific WU before training appears to improve speed and strength performance compared to no WU in school-age children. However, the effects of WU on endurance and flexibility performance in school-age children need to be further investigated. In any case, it is recommended that WU should be implemented before any training or PE session, regardless of the improvement in performance, because of its physiological effects and activation of the body in school-age children.

References

1. Gómez-Álvarez N., Schweppe-Villa A., Parra-Gatica A., Cid--Rojas F., Pavez-Adasme G., Hermosilla-Palma F. (2021). Acute effects of different warm-up strategies in physical performance and motor skills in scholars. *Retos: Nuevas Tendencias en Educación Física, Deporte y Recreación* 42, 18-26. DOI:10.47197/retos.v42i0.86525 [in Spanish]
2. Kar S., Banerjee A. (2013). Influence of active and passive warming up on motor performance of the athletes. *IOSR Journal of Humanities and Social Science* (IOSR-JHSS) 10(6), 14-21.
3. Coledam D.H., Aires de Arruda G., Ramos de Oliveira A. (2012). Chronic effect of static stretching performed during warm-up on flexibility in children. *Brazilian Journal of Kinanthropometry and Human Performance* 14(3), 296-304. DOI: 10.5007//1980-0037.2012v14n3p296
4. Bishop D., Middleton G. (2013). Effects of static stretching following a dynamic warm-up on speed, agility and power. *Journal of Human Sport and Exercise* 8(2), 391-400. DOI: 10.4100/jhse.2012.82.07
5. Singh S., Singh V. (2015). Effect of different types or warm up on pull ups. *International Journal of Movement Education and Sports Sciences (IJMESS)* 3(1), 81-85.
6. Gelen E. (2011). Acute effects of different warm-up methods on jump performance in children. *Biology of Sport* 28(2), 133-138. DOI: 10.5604/947456
7. Iacono A., Vigotsky A., Laver L., Halperin I. (2019). Beneficial effects of small-sided games as a conclusive part of warm-up routines in young elite handball players. *Journal of Strength and Conditioning Research* 35(6), 1724-1731. DOI: 10.1519/JSC.0000000000002983
8. Vleugels L.W.E., Swinnen S.P., Hardwick R.M. (2020). Skill acquisition is enhanced by reducing trial-to-trial repetition. *Journal of Neurophysiology* 123(4), 1460-1471. DOI: 10.1152/jn.00741.2019
9. Chang N.J., Tsai I.H., Lee C.L., Liang C.H. (2020). Effect of a six-week core conditioning as a warm-up exercise in physical education classes on physical fitness, movement capability, and balance in school-aged children. *International Journal of Environmental Research and Public Health* 17(15), 5517. DOI: 10.3390/IJERPH17155517
10. Çelik M.A., Özdal M., Vural M. (2021). The effect of inspiratory muscle warm-up protocol on acceleration and maximal speed in 12-14 years old children. *European Journal of Physical Education and Sport Science* 6(11), 104-111. DOI: 10.46827/ejpe.v6i11.3642
11. Ruiz Garrigos A., de Vincente Duran A., Sanchez-Pay A. (2020). Influence of two types of warm-ups on the explosive force of the lower body in physical education students. PENSAR EN MOVIMIENTO: *Revista de Ciencias del Ejercicio y la Salud* 18(1), 1-13. DOI: 10.15517/pensarmov.v18i1.34705. [in Spanish]
12. Gerdijan N., Peric D., Ljubojevic A., Vukic Ž. (2021). Effects of static and dynamic stretching exercises on unilateral hamstring to quadriceps strength ratio. *Advances in Physical Educatio*n 11(1), 89-102. DOI: 10.4236/ape.2021.111007
13. Faigenbaum A.D., McFarland J.E., Kelly N.A., Ratamess N.A., Kang J., Hoffman J.R. (2010). Influence of recovery time on warm-up. Effects in male adolescent athletes. *Pediatric Exercise Science* 22(2), 266-277. DOI: 10.1123/pes.22.2.266
14. Carvalho F.L.P., Rayol J.E.L., Gurgel de Alencar M.C., Martin E.H. (2009). Acute effects of static stretching and proprioceptive neuromuscular facilitation on the performance of vertical jump in adolescent tennis players. *Fitness & Performance Journal* 4, 264-268.
15. Merino-Marban R., Fuentes V., Torres M., Mayorga-Vega D. (2021). Acute effect of a static- and dynamic-based stretching warm-up on standing long jump performance in primary schoolchildren. *Biology of Sport* 38(3), 333-339. DOI: 10.5114/biolsport.2021.99703
16. Zmijewski P., Lipinska P., Czajkowska A., Mróz A., Kapuściński P., Mazurek K. (2020). Acute effects of a static vs. a dynamic stretching warm-up on repeated-sprint performance in female handball players. *Journal of Human Kinetics* 72(1), 161-172. DOI: 10.2478/hukin-2019-0043
17. Ayala F., Sainz de Baranda P., De Ste Croix M. (2012). Stretching in warm-up: Design of routines and their impact on athletic performance. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte* 12(46), 349-368. [in Spanish]
18. Ayala F., Sainz De Baranda P., Cejudo A., De Ste Croix M. (2011). Acute effect of stretching on physical performance: the use of stretching exercises in warm-up. *Cultura, Ciencia y Deporte* 6, 27-36. [in Spanish]
19. Cooper H., Hedges L.V., Valentine J.C. (2009). *The handbook of research synthesis and meta-analysis*. 2nd edition. Russell Sage Foundation.
20. Howe C.A., Mahon A.D., Everhart J., Gay J.A., Sherwood J.J. (1995). The effects of warm-up intensity on anaerobic performance and recovery in male children. *Medicine & Science in Sports & Exercise* 27(5), 113.
21. Rezende F.N., Mota G.R., Lopes C.R., Silva B.V.C., Simim M.A., Marocolo M. (2016). Specific warm-up exercise is the best for vertical countermovement jump in young volleyball players. *Motriz: Revista de Educação Física* 22(4), 299-303. DOI: 10.1590/S1980-6574201600040013
22. Duncan M.J., Woodfield L.A. (2006). Acute effects of warm up protocol on flexibility and vertical jump in children. *Journal of Exercise Physiology online (JEPonline)* 9(3), 9-16.
23. Ray A., Mandal A.K. (2018). Comparative study of active, passive and no warm-up on selected physical fitness performance of inter-university players. *International Journal of Physical Education, Sports and Health* 5(2), 150-154.
24. Muanjai P., Jones D.A., Mickevicius M., Satkunskiene D., Snieckus A., Skurvydas A. et al. (2017). The acute benefits and risks of passive stretching to the point of pain. *European Journal of Applied Physiology* 117(6), 1217-1226. DOI: 10.1007/S00421-017-3608-y
25. Andrejić O. (2012). An investigation into the effects of different warm-up protocols on flexibility and jumping performance in youth. *Physical Education and Sport* 10(2), 107-114.
26. Manjre U.N. (2020). Comparative study of active, passive and no warm up on selected physical fitness performance of cricket players. *Aayushi International Interdisciplinary Research Journal* (AIIRJ) 7(4), 75-77.
27. Faigenbaum A.D., Kang J., Ratamess N.A., Farrell A., Choma M., Mercado H. et al. (2020). Dynamic warm-up effects on maximal treadmill exercise performance in children: A pilot study. *Medicine & Science in Sports & Exercise* 52(7S), 59. DOI: 10.1249/01.mss.0000670656.78661.7b
28. Needham R.A., Morse C.I., Degens H. (2009). The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. *Journal of Strength and Conditioning Research* 23(9), 2614-20. DOI: 10.1519/JSC.0b013e3181b1f3ef

29. Zourdos M.C., Bazyler C.D., Jo E., Khamoui A.V., Park B.S., Lee S.R. et al. (2017). Impact of a submaximal warm-up on endurance performance in highly trained and competitive male runners. *Research Quarterly for Exercise and Sport* 88(1), 114-9. DOI: 10.1080/02701367.2016.1224294
30. Takizawa K., Yamaguchi T., Shibata K. (2018). Warm-up exercises may not be so important for enhancing submaximal running performance. *The Journal of Strength and Conditioning Research* 32(5), 1383-1390. DOI: 10.1519/JSC.0000000000001970
31. Liao T., Yu Y., Wang B. (2017). Effect of the functional dynamic warm-up on speed, power and core muscle endurance for adolescent. In P. Salomon, A.C. Macquet (eds) *Advances in Human Factors in Sports and Outdoor Recreation* (pp. 97-108), Springer. DOI:10.1007/978-3-319-41953-4_9
32. Pagaduan J.C., Pojskić H., Užičanin E., Babajić F. (2012). Effect of various warm-up protocols on jump performance in college football players. *Journal of Human Kinetics* 35, 127-132. DOI: 10.2478/v10078-012-0086-5
33. Alvarez-Fernandez M.P., Chaverri-Rodriguez M.A., Quiros--Vasquez A., Carazo-Vargas P. (2021). Effects of warm-up in 100 m crawl performance in collegiate swimmers. *EmasF: Revista Digital de Educación Física* 12(70), 114-122. [in Spanish].

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