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Differences between barefoot and shod performance in selected fitness tests in adolescents

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Abstract

Physical fitness is an important health indicator and component of physical literacy. Therefore, monitoring youth fitness performance is crucial for identifying potential health risks and tracking physical literacy development. Over the years, many fitness test batteries have been developed while different protocols for footwear have been used in fitness testing. The comparison of fitness results performed in different footwear could therefore be questioned. Thus, the purpose of this study was to examine the differences between barefoot and shod performance of selected motor tests in adolescents. Eighty-six adolescents aged between 14 and 16 years performed standing long jump, 20-m shuttle run, and polygon backwards in both footwear conditions. A strong correlation (r=0.83-0.95) was noted between both performances. No significant differences between barefoot and shod performance in the standing long jump and the backward obstacle course test were found, while significant differences were noted in the 20-m shuttle run. In this test, both, boys and girls performed better in shod conditions. Interestingly, there were no significant differences in performance of all tests among those who are habitually barefoot and others. From practical perspective, this study demonstrated that researchers could compare scores of samples in barefoot and shod performance of standing long jump and backward obstacle course tests. However, when physical teachers compare individual scores over the years, this should be made under the same footwear conditions, as differences in test conditions can provide a distorted picture of motor development.

Keywords: *physical fitness, motor test, coordination, shuttle run, standing long jump, athletic footwear, kinematics, running*

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Introduction

Physical fitness is a good indicator of health status among youth (Ortega et al., 2008). Higher fitness levels suggest better health outcomes in children and adolescents (Ortega et al., 2008) while physically less fit individuals tend to be at higher risk for developing chronic diseases (Högström et al., 2015; Hurtig-Wennlöf et al., 2007; Lätt et al., 2016), mental health disorders (Ortega et al., 2008) and are at higher risk for all-cause mortality (Ortega et al., 2012; Sato et al., 2009). Monitoring physical fitness is especially important at a young age considering that physically fit children and adolescents are more likely to become physically fit and active

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adults (Malina, n.d.). Since positive effects of physical activity on health can be seen in adulthood Ortega and colleagues (2008) recommend physical fitness testing and health monitoring already in childhood and adolescence.

Many test batteries have been developed for physical fitness testing of youth and adults over the years (Council of Europe, 1993; Jurak et al., 2019; Kolimechkov, 2017; Mood et al., 2007; Ruiz et al., 2011; Shingo & Takeo, 2002; Vanhees et al., 2005). Although test batteries are standardized, there are many modifications of specific tests that appear in the literature. Moreover, when performing motor tasks, including running and jumping, footwear can differ between subjects, which can alter motor performance. These different conditions are constraints that could promote or interfere with the results of fitness tests. Robinson and colleagues (2011) highlight the importance of footwear when testing motor skill performance in young children and teaching them locomotor skills.

Several studies evaluated biomechanical differences in locomotion of children and adolescents between shod and barefoot conditions and concluded that there are kinematic and kinetic differences when comparing running and walking, yet no changes were observed in jumping tasks (Khajooei et al., 2020; Wegener et al., 2011). Much less is known about the effect of two conditions on motor performance.

Harry and colleagues (2015) examined the effects of footwear on jumping tasks in adults and found that jump performance was perceived equal between shod and barefoot condition in both standing long jump and vertical jump. On the contrary, La Porta and colleagues (2013) showed better vertical jump performance when adults were barefoot (LaPorta et al., 2013). Researchers assume this might be due to the cushion of the shod condition where applied forces dissipate instead of transition into the ground during the propulsion phase. Another study on 810 children and adolescents in age range 6-18 years included two groups of participants that were either habitually shod or habitually barefoot (Zech et al., 2018). When standing long jump performance was compared between groups, habitually barefoot participants jumped further in standing long jump with the largest difference among participants being observed in adolescents. When comparison was done within groups, habitually barefoot participants continuously performed better without shoes, however no differences were found between barefoot and shod condition in habitually shod participants. On the contrary, researchers in a smaller study showed that children jumped further with shoes (Wegener et al., 2012) .

When comparing running barefoot and shod most studies focus on the biomechanical aspect and much less is known about its effect on motor performance. One study in adults showed that running with shoes presents a significantly higher oxygen cost than running barefoot and the authors concluded that barefoot running is more economical than running shod (Hanson et al., 2011). On the contrary, when shorter running distances were used, habitually shod children and adolescents performed better. Surprisingly, when the same participants were compared in both condition no difference was observed in the 20-meter sprint test (Zech et al., 2018).

Physical fitness testing for children and adolescents usually happens during physical education classes where children are shod or barefoot. There is a concern that the assessment of adolescents' motor performance could be compromised by footwear conditions. Moreover, modifications of some fitness tests exist, and their use worldwide is not standardized. Thus, comparison of results for similar motor tasks in different conditions is difficult among studies. It seems that, there are no clear effects of shod or barefoot conditions on motor performance in children and adolescents. The purpose of the study was to examine differences in adolescents' motor performance in different footwear conditions. Based on the current evidence it was hypothesised that no difference will be observed between the barefoot and shod condition in selected motor tasks that are used in fitness testing: standing long jump (explosive strength), 20-m shuttle run (cardiovascular endurance), and polygon backwards (coordination of whole-body movement).

Methods

Study sample and design

Data were collected within the ACDSi study, approved by the Slovenian National Medical Ethics Committee (ID 52/03/14), following the Declaration of Helsinki. The ACDSi is a cross-sectional decennial study that includes 16 upper secondary schools and investigates adolescents' biological, psychological and social development, described in detail elsewhere (Starc et al., 2015). A national, representative sample was selected for the ACDSi 2014 study using a multi-stage, stratified design. Written, informed consent was obtained from parents or legal guardians of all adolescents before voluntary participation; adolescents could withdraw from the study, in whole or in part, anytime they wished. For the purpose of the present study 86 adolescents (28 male) aged between 14 and 16 years (14.8 ± 0.6) from the initial sample were included in the analysis. All participants in this subsample were first year students at upper secondary schools and completed all fitness tests in barefoot and shod condition. To examine potential bias, we compared results of used motor tests between age-matched participants in sample and subsample and found that there were no statistically significant differences among them.

Data collection was performed by a team of researchers well-familiarised with all test protocols. Fitness testing took place indoors (room temperature ranged between 20-24°C), between 8:00‑14:00 lasting two or three days for each school involved. All data collection took place in the academic fall term, September-October 2014. Each adolescent was present for measurements on two days. Participants completed 20-m shuttle run test on one day and remaining fitness tests on other day. During the first measurement period all participants performed motor tests in barefoot condition. After two weeks the same participants completed same motor tests in shod condition with athletic footwear.

Fitness tests

Physical fitness tests were performed and scored using SLOfit (Strel et al., 1997) and EUROFIT (CDDS, 1983) protocols.

Standing long jump

Explosive power was assessed by standing long jump test. Participants stood behind a labelled take-off line and were instructed to jump as far as possible. A two-foot take-off and landing was used, with swinging of the arms and bending

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of the knees to provide forward drive. The jump distance was measured manually from the take-off line to the nearest point of contact on the landing, usually back of the hell. The best of three attempts was recorded, and the result was given in centimetres.

Backwards obstacle course

Backwards obstacle course was used to assess coordination of whole-body movement. Participants had to manoeuvre over a set polygon by moving backwards supported by their hands and feet on the ground as fast as possible. Participants began the test behind the starting line with feet behind the line (backwards on all fours). After three meters participants had to climb over the upper part of Swedish chest (a total height = 50 cm). After additional 3 meters (6 meters from starting line) a frame of Swedish chest was placed perpendicular to the corridor and participants had to crawl through it. Participants had to cross the finish line on their feet and hands on the ground, which was placed 10 meters from the starting line. The time stopped when participants crossed the finish line with their hands. The best of two attempts was recorded and the result was rounded up to the nearest tenth of a second.

20-m shuttle run

Léger's original 20-m shuttle run protocol (Léger et al., 1988) was conducted indoors to determine cardiovascular endurance and it involved continuously running between two lines 20 meters apart in time to audio signals. It consisted of multiple stages which lasted approximately one minute, starting at a speed of 8.5 km/h and increases by 0.5 km/h every minute thereafter. With stage progression the required running speed increased until volitional fatigue or when participant was no longer able to complete the distance of 20 meters in-line with the audio signal. Participants stood behind the first line, facing second line, and began running when instructed by the audio signal. If participants reached the line before the signal, they had to wait for the signal to continue running. Participants had to keep running and complete as many stages as possible in time to reach the lines before the audio signal. The test ended when participants were not able to reach the line on two consecutive audio signals. The result was the last level in which participants successfully reached the lines. These results can further be used to calculate maximal aerobic power of the participants (Léger et al., 1988).

Habit to be barefoot

In addition, we asked subjects during second fitness testing if they are used to walk and run barefoot. Dichotomous variable was constructed from their replies.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 27 (IBM Corporation, Chicago, IL, USA). Descriptive statistics were calculated for age, gender and all motor tasks and presented as means, standard deviations, medians, and interquartile ranges where appropriate. Paired sample t-test and Wilcoxon signed-rank test were used to assess differences among conditions. Cohen's d was calculated as effect size measure for statistically significant results. Bland–Altman plots were used to present systematic and random (individual) differences between performance in both conditions. To determine relationship between barefoot and shod performance, Pearson correlation coefficients were calculated. Levene's test and ANOVA was used to compare how habitually barefoot condition affects the results when participants perform fitness tests barefoot and shod. An a priori Alpha of 0.05 was used to determine significance.

Results

Descriptive data of motor performance for both test conditions are shown in Table 1. There were no statistically significant differences among barefoot and shod conditions in standing long jump distance (p=0.063), although on average boys performed slightly better in barefoot condition. Likewise, performance in backwards obstacle course did not differ between both conditions in boys or girls, although boys had slightly better (shorter) times for shod condition and the opposite was true for girls. Shuttle run performance was significantly better (more stages run) in shod condition for both, boys and girls (p<0.001, ES=0.71 for boys, p<0.001, ES=0.47 for girls, respectively).

Table 1. Descriptive data of standing long jump, backwards obstacle course and 20-m shuttle run performance divided by gender and both test conditions (barefoot vs. shod testing).

Fitness test		Male (N = 28)	Female (N = 58)
Standing long jump (cm)	Barefoot	208±24.2	170.5±16.7
	Shod	204.7±24.8	170.3±17.1
Backwards obstacle course (s)	Barefoot	11.1±3.4	12.6±2.4
	Shod	10.7±2.3	12.9±2.6
20-m shuttle run (stages)	Barefoot	8±4*	5±6*
	Shod	9±3*	6±3

Notes: Values for the standing long jump and backwards obstacle course tests are presented as mean±SD; values for the 20-m shuttle run test are presented as median±IQR; * significant differences between barefoot and shod conditions (p<0.05).

There were significant and strong correlations between barefoot and shod performance for all fitness tests. The strongest correlation was noticed in standing long jump (r=0.95, p<0.001), followed by backwards obstacle course (r=0.84, p<0.001), and 20-m shuttle run test (r=0.83, p<0.001).

Figure 1 shows relationship between results in shod and barefoot condition for all tests.

No significant differences in the results in those who are habitually barefoot and those who are habitually shod were noted in standing long jump distance (p=0.098), backwards obstacle course (p=0.563), and 20-m shuttle run test (p=0.704).

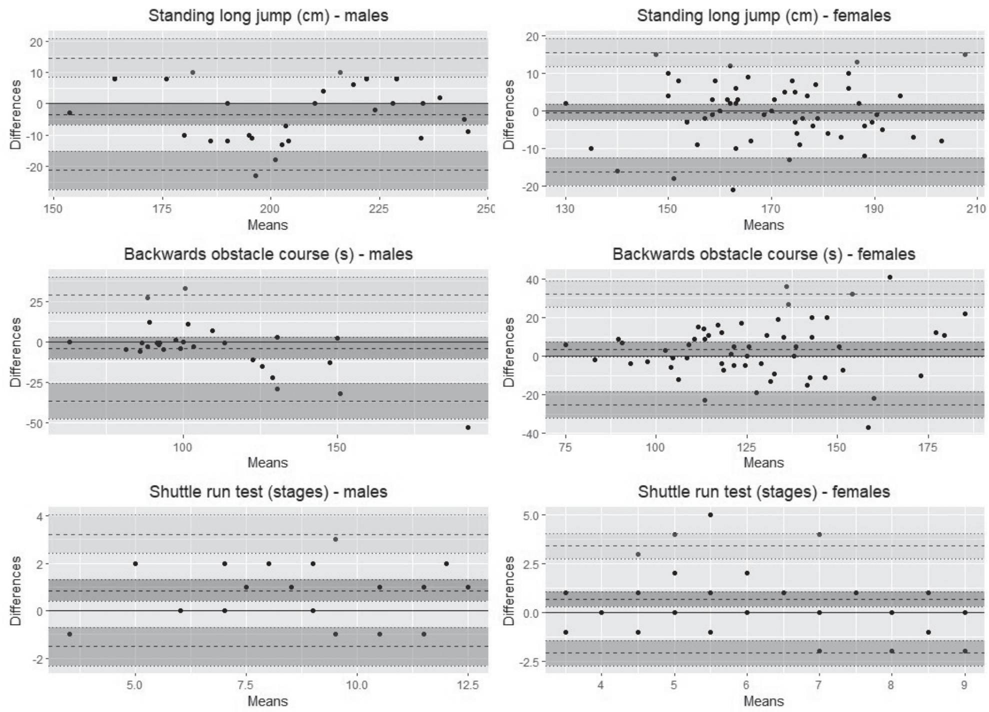

Figure 1. Bland–Altman plots of the relationship between results in shod and barefoot condition for all tests (difference = shod minus barefoot performance).

Discussion

The purpose of this study was to determine whether there is a difference when adolescents perform fitness tests barefoot or wearing athletic footwear. First important finding is that there is a strong correlation (r=0.83-0.95) between barefoot and shod performance of selected fitness tests. Second, there were no significant differences in results of the standing long jump and the backward obstacle course performed barefoot or shod. Third, significant differences performing 20-m shuttle run in barefoot or shod conditions were found, whereby both, boys and girls performed better in shod running. Interestingly, there were no significant differences in test results in those who are habitually barefoot and those who are habitually shod.

Many studies have examined the biomechanical differences in locomotion of children and adolescents between shod and barefoot conditions (Khajooei et al., 2020; Wegener et al., 2011), however, much less is known about whether performing tests shod or barefoot affects motor performance. In this study, three fitness tests were used to investigate these differences.

A strong correlation and no significant differences between performing standing long jump barefoot and shod were found in our study. This is consistent with previous findings on children aged 4 to 7 years (Khajooei et al., 2020), children aged 8 to 12 years (Wegener et al., 2013), and adults (Harry et al., 2015). Namely, standing long jump is a fundamental movement pattern and it has been shown that jump performance depends on a variety of factors such as level of upper and lower body coordination (Wu et al., 2003), application of proper jumping technique, body power, countermovement and take off angle (Zhou et al., 2020). According to the literature, the longest jump is achieved when using arm motion with feet in a straddle position (Mackala et al., 2013), and when take-off angle is less than 45 degrees. All these biomechanical variables improve take-off velocity of centre of mass and increase the power in the lower extremities which affects long jump performance (Zhou et al., 2020). Moreover, one kinematic study (Fernandez-Santos et al., 2018) in children showed that 51 % of jump distance variance is accounted by sex, age and body mass index and that among kinematic variables take-off distance and take-off speed were most important. To the best of our knowledge, no studies have compared biomechanical aspects between barefoot and shod condition in children and adolescents, however, motor performance studies show that there are no differences between conditions (Zech et al., 2018). Thus, we can assume that shod conditions represent such small variance of performance in standing long jump that this does not affect scores when we observe this on group level. However, we should be more careful on individual level. Although there were no statistical differences among footwear conditions performing this test, boys scored on average 3.3 cm better when they were barefoot, whereas almost no differences were found in girls. This could be an important difference when evaluating individual results, especially in fitness monitoring, when results of certain individual are compared within some period.

Next, a strong correlation and no significant difference were also found between performing backward obstacle course barefoot and shod. This fitness test indicates on the coordination of whole-body movement. It is performed at the same time on all four limbs; therefore, importance of footwear should be logically lower, however all movement is performed backwards which represents somehow specific placement of foot which could influence speed of foot movement. By our best knowledge, no similar study was done in the past. Therefore, we cannot compare our results with previous findings. However, from perspective of physical education practice such results were expected, since teachers do not notice specific problems of students when performing such kind of movements barefoot.

Opposite to other two fitness tests, significant differences

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between shod and barefoot performance were noted in 20-m shuttle run, although correlation between performance in both conditions was strong. Better scores were achieved in shod condition in boys and girls. Based on previous findings we explain such differences with better body mass handling when performing test shod in our subjects. Namely, 20-m shuttle run test consists of accelerated running at the beginning, then steady running, stopping, and changing direction, which is similar to agility tests, especially at high velocity. At such movements athletic footwear can play a role as it was shown in some studies. Wegener et al. (2015) reported that gait velocity increased during walking and running with shoes in children aged 8 to 10 years. Lythgo et al. (2009) also reported that gait speed and step length increased when wearing shoes. However, Wegener et al. (2012) found no differences between barefoot running and running with shoes in an agility test in nineteen children aged 10 years. The same was reported by Khajooei et al. (2020), who studied fourteen children aged 4 to 7 years and found that the children's gait velocity remained unchanged when they walked barefoot or with shoes. However, participants in our study were much heavier (at least 20 kg) and they run faster (on average with final speed 11 – 12.5 km/h) than participants in mentioned studies, including turning at each side of the line. Thus, they had to tackle greater forces on their feet. This was also noticed in the barefoot test performing where some participants got blisters during changing the running direction.

Interestingly, there were no significant differences in all three test results in those who are habitually barefoot and those who are habitually shod. In 20-m shuttle run, most participants who are habitually barefoot run better when barefoot, while those who are habitually shod had similar results when running shod or barefoot. This is somehow opposite to findings of Zech et al. (2018) who found that habitually shod children aged 11-14 years had significantly faster 20-m sprint time compared with habitually shod children, whereas no differences were found between groups in the standing long jump and balance test.

Based on our knowledge, this is the first study to examine how footwear affects adolescent motor performance, including whole-body movement coordination, explosive power, and cardiovascular endurance. However, the results of this study should be considered with following limitations: a) reliability of selected fitness tests and possible interpersonal differences in both conditions performance could blur real correlations between barefoot and shod performance; b) small sample of adolescents who are habitually barefoot can affect the results of analysis difference between habitually barefoot and shod adolescents' test scores.

Conclusions

Findings of this study have practical implications for researchers on physical fitness and physical education teachers who are monitoring fitness of their students. Researchers use different protocols in fitness testing associated with footwear, therefore comparing fitness results between studies could be questioned. This study demonstrated that researchers could compare samples' scores in barefoot and shod performance of fitness tests similar like standing long jump and backward obstacle course. However, some caution compering running tests with changing direction (e.g., shuttle run or the agility tests) should be applied. However, when it comes to comparison of individual results, like it is in annual fitness monitoring in schools, it is important for physical education teacher to consider that students perform tests in same footwear conditions as before, since differences can provide distorted picture about their motor development.

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Conflict of interest

There is no conflict of interest.

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