

VERTICAL JUMP HEIGHT IN YOUNG CHILDREN – A LONGITUDINAL STUDY IN 4- TO 6-YEAR-OLD CHILDREN

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ABSTRACT

Preschool children are intensively involved in the process of developing fundamental movement skills such as walking, running, jumping, climbing, crawling and other simple movements. We aimed to compare age- and gender- related trends in countermovement vertical jump (CMJ) performance (jumping height) measured with a means of ground force plate during a longitudinal study of 4- to 6-year old children (N=79; 43% boys). Furthermore, we classified children CMJ arm-leg coordination into poor, average, or excellent on the grounds of high speed video footage. We found that CMJ height progresses significantly with age when arms are used ($P<.001$; $\eta^2=.632$) and without the use of arms ($P<.001$; $\eta^2=.620$). There were no sex effects. After classification of CMJ arm – leg coordination we found that children with excellent CMJ coordination progress more intensively than those with average coordination, whereas poorly coordinated jumpers do not progress at all. After extrapolating our data with the data of others we found logarithmic CMJ height trends until the age of 16 in both sexes, athlete boys jumping higher than the non-athletes after the ages of 14 or 15. It seems that the initial movement patterns level, in this case the observed jumping technic, develops and refines in 4- to 6-year old children at that age. We conclude that jumping coordination is a very important factor of CMJ performance in the studied age span.

Keywords: countermovement jump; ground force plate; coordination, explosive power, pre-school children.

RAZVOJ NAVPIČNEGA SKOKA OTROK - LONGITUDINALNA ŠTUDIJA 4- DO 6-LETNIH OTROK

IZVLEČEK

Predšolski otroci so intenzivno vključeni v proces razvoja elementarnih gibalnih vzorcev, kot so hoja, tek, skok, plezanje, plazenje in drugih enostavnih gibanj. Naš namen je longitudinalno primerjati uspešnost skoka z nasprotnim gibanjem - CMJ (višina skoka) merjeno s tenziometrijsko ploščo 4 do 6 let starih otrok (N=79; 43% dečkov) glede na starost in spol. Poleg tega smo otroke razvrstili glede na CMJ koordinacijo med rokami in nogami v slabše, povprečne ali odlične na podlagi visokofrekvenčnih video bočnih posnetkov. Ugotovili smo, da CMJ višina narašča z leti, pri skokih z uporabo rok ($P < ,001$; $\eta^2 = ,632$) in brez uporabe rok ($P < ,001$; $\eta^2 = ,620$). Med spoloma ni bilo razlik. Po klasifikaciji koordinacije CMJ smo ugotovili, da otroci z odlično koordinacijo CMJ napredujejo intenzivneje kot tisti s povprečno koordinacijo CMJ, medtem ko otroci s slabšo koordinacijo CMJ sploh niso napredovali. Po ekstrapolaciji naših podatkov z drugimi, smo ugotovili logaritemski trend višine CMJ do starosti 16 let pri obeh spolih, kjer po starosti 14-15 let fantje športniki skočijo višje kot fantje, ki niso športniki. Ugotavljamo intenziven trend razvoja CMJ v tem starostnem obdobju, kjer je koordinacija CMJ zelo pomemben dejavnik uspešnosti izvedbe CMJ.

Ključne besede: skok z nasprotnim gibanjem, tenziometrijska plošča, koordinacija, eksplozivna moč, predšolski otroci

INTRODUCTION

The reported children sedentary behavior (Carson, LeBlanc, Moreau, & Tremblay, 2013; Colley et al. 2011; ParticipACTION 2015, 2016) and obesity (Gotay et al. 2013; Ng et al. 2014) are among the major health problems. The epidemic of physical inactivity and the associated epidemic of obesity are being driven by multiple factors: societal, technologic, industrial, commercial, financial (Council on Sports Medicine and Fitness and Council on School Health, 2006). Obesity among children in Slovenia is increasing. The data collected in the context of the European initiative show that the Slovenian children are among the most endangered of obesity among the EU countries (OECD/EU, 2016). This global trend of prolonged sitting and obesity is likely to continue due to the growing availability and popularity of computer, mobile phones, video games and television (Lepp, Barkley, Sanders, Rebold, and Gates, 2013; Public Health England, 2013) and due to less favorable food availability (Raychaudhuri & Sanyal 2012; Skidmore & Yarnell, 2004). Moreover, we must be aware that health behaviors and obesity is transferred into adulthood.

On the other hand, physical activity and exercise helps preventing chronic diseases such as cardiovascular disease (Kruk, 2007; Warburton, Nicol, & Bredin, 2006), diabetes (Kruk, 2007; Warburton, Nicol, & Bredin, 2006), cancer (Kruk, 2007; Warburton, Nicol, & Bredin, 2006), hypertension, obesity (Kruk, 2007; Warburton, Nicol, & Bredin, 2006), osteoporosis (Kruk, 2007; Warburton, Nicol, & Bredin, 2006), fall-related injuries (Kruk, 2007), depression (Kruk, 2007; Warburton, Nicol, & Bredin, 2006) and emotional stress (Kruk, 2007). Therefore, it is essential to encourage preschool children to engage healthy lifestyle as early as possible, to develop motor abilities satisfactory and develop fundamental movement skill (FMS) such as walking, running, jumping, crawling, climbing, hopping, catching, kicking, throwing and hitting a ball. If sufficiently developed, FMS plays an important role in establishing physical confidence and competence (Gallahue and Ozmun, 1998).

FMS development has been classified into stages, progressing from a beginner level to a mature level (Hynes-Dusel, 2002). The beginner level generally depicts the minimal standard of children ages 4 to 7 (Gabbard, 1992). By the completed age of 8, with practice and maturity, most children will have achieved mature level (Gabbard, 1992). The experts believe that motor delays negatively influence future motor and cognitive development (Gallahue, 1996). Therefore, mastering FMS is linked also to cognitive development (Diamond, 2000; Krombholz, 1997).

Most of the studies reports FMS data obtained in adult male subjects (Laffaye and Choukou, 2010; Harman, Rosenstein, Frykman, & Rosenstein, 1990; Marković, Dizdar, Jukić, & Cardinale, 2004; Marković, 2007; Runge, Rittweger, Russo, Schiessl, & Felsenberg, 2004) and there are few longitudinal data about children development trends of both sexes where the most frequent FMSs observed are walking and the vertical jump (Focke et al., 2013). Different researchers defined the factors affecting vertical jump ability: a) composition of skeletal muscles (Kaneko, Fuchimoto, Toji, & Suei, 1983; Wilson, Newton, Murphy, & Humphries, 1993), b) well-developed alactic or anaerobic power capacity (in comparison with the athletes with high aerobic power capacity) (Shorten, 1987; Conlee, McGown, Fisher, Dalsky, & Robinson, 1982), c) neural adaptation (motor unit activation, motor unit synchronization and the specificity of the movement pattern (Wilson et al., 1993; Sale, 1988), d) initial levels of strength of the person and the ability to make use of a stretch shortening cycle (Adams, O'Shea, O'Shea, & Climstein, 1992; Duke & BenEliayhu, 1992; Wilson, Newton, Murphy, & Humphries, 1993), e) the use of elastic and contractile energy for producing dynamic muscle contractions (Adams et al., 1992; Duke & BenEliayhu, 1992), f) effective use of the arms for increased vertical velocity (Harman et al., 1990), g) trunk extension, head movements and utilization of a countermovement to initiate the stretch shortening cycle (Young, 1995; Van Soest, Robbroeck, Bobbert, Huijing, & van Ingen Schenau, 1985; Harman et al., 1990), h) upper body and abdominal (trunk) strength has also shown to be a contributing factor to vertical jump performance (Shorten, 1987; Cisar & Corbelli, 1989; Bobbert & Van Soest, 1994), and i) development of a motor pattern for vertical jump – arm swing (Young, 1995). All the above-mentioned factors develop through childhood and, thus, this development must affect vertical jump development as well as other FMS.

There have been numerous studies which have investigated jumping in adult athletes from various sports, and the most commonly reported parameter is jumping height. However, it is difficult to compare the results of various studies as they all vary greatly in the experimental design, in the duration of research, in the testing procedures utilized and in the application of training techniques. Although vertical jumping is often used in physical performance tests for both children and adults, normative data for children are lacking in the literature. Only few studies focused on jumping performance in primary and secondary school children (Klausen, Schibye, & Rasnussen, 1989; Temfemo, Hugues, Chardon, Mandengue, & Ahmaidi, 2009; Focke et al., 2013) and some in pre-school children (Neelly & Zebas, 2003; Harrison & Moroney, 2007; Focke et al., 2013). Neelly and Zebas (2003) where a research was performed on a 4.5 year-old children, while Focke et al. (2013) measured 1835 children aged from 4 to 17 years of age. They specified that boys jump higher than girls and reported cross-sectional developmental trends for both sexes.

Therefore, we aimed to develop longitudinal CMJ height trends in 4- to 6 year-old children for both sexes. Additionally, our goal is to detect the jumping technique used by children. When comparing CMJ height in children classified with different jumping coordination score (1 – poor; 2 – average; 3 – excellent) we hypothesized that the percentage of excellent jumpers would increase and excellent jumpers would progress in CMJ height more intensively with their age. We also plan to extrapolate CMJ height age trends with the data of others.

METHODS

Participants

Four-year-old children were recruited in 2009 from three randomly selected Slovenian kindergartens, all in the Coastal region: Koper, Škofije and Semedela. All tests and procedures were explained to the parents on organized meetings in kindergartens prior to the obtainment of their written consent. None of the children had any history of neuromuscular disorders or muscle diseases. In regard to the recruitment process, 160 children in total were selected (only those who had their 4th birthday in 2009), of which 79 children (34 boys, 45 girls) completed all three longitudinal jumping measurements and were selected for the analysis. Moreover, all procedures conformed to the 1964 Declaration of Helsinki and were approved by the National Medical Ethics Committee of the Republic of Slovenia.

Procedures

The organizational settings of the conducted longitudinal study were the same for all three assessments. The assessments were conducted in autumn of 2009, 2010, and

2011. A week before the assessment we notified the teachers to follow a specific protocol prior to the measurement, namely, that all major physical or sport activities were discouraged two days before the assessment. Daily, from 2 to 5 children arrived in the laboratory and performed a series of tests (body composition, muscle architecture, posture analysis, and five FMS analysis) from where only basic anthropometrical data and vertical jumping is presented in this report.

Measurements of Anthropometrical Characteristics

All children had their standing height and weight measured. Participants' body mass and height were measured by a means of standard tools. Their body mass was measured to an accuracy of .1 kilograms, while the body height was measured to an accuracy of .5 centimeters. All participants were barefoot and wearing their sportswear during the measurements. The body composition was measured with bioimpedance (BioScan 916s, Maltron, UK), where children lied on a bed for 30 minutes before the assessment.

Countermovement Jumping Height Assessment

Each child performed a 15 minutes of standardized warm-up before the FMS assessment. After the walking and running analysis we analysed jumping performance. The instruction was to jump as high as possible, using their arms and countermovement jumping (CMJ) technique. Each child performed between 3 and 5 trial jumps followed by three maximal CMJs with the use of their arms and three maximal jumps without the use of their arms on a ground force plate system (AMTI sampling at 1000 Hz.). They were also simultaneously videotaped with high-frequency camera (Fujifilm Finepix HS10) for qualitative analysis of arm-leg coordination and synchronization of movement. During each jump, there was at least one minute of rest. CMJ height was calculated based on the flight time. The highest jumps from both techniques (with and without the use of the arms) were taken for further analysis. We used several motivational methods to achieve a maximal performance (wall stickers), similarly as in some previous studies where they used balloons (Clark, Phillips, & Petersen, 1989; Jensen, Phillips, & Clark, 1994).

Countermovement Jumping Coordination Assessment

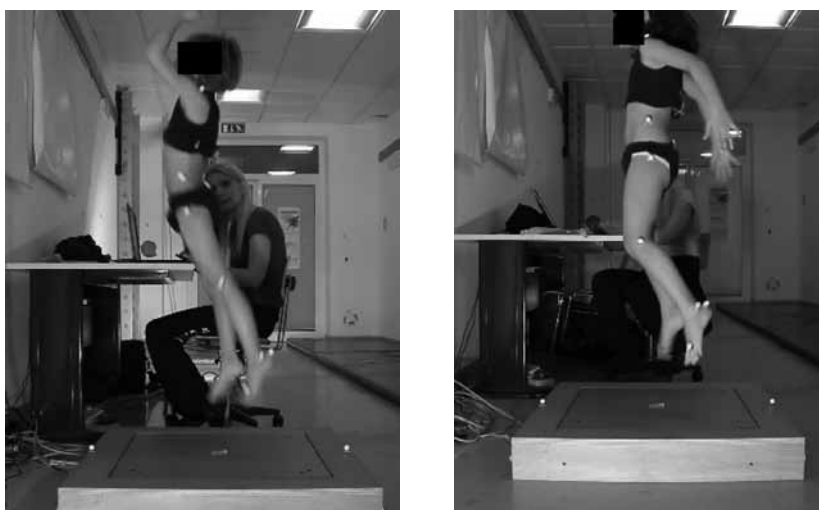
For the jumping coordination assessment, we used a scale developed by Plevnik (2014) adapted from the technique for the evaluation of the implementation of motor tasks (Vies, Kroes & Feron, 2004), where jumping coordination was qualitatively (based on high-speed video footage, see Figure 1) classified as:

POOR (score 1): Hands do not follow the body movement. They move backwards, or not at all.

AVERAGE (score 2): Hands are somewhat included in jumping performance, but less intensively or with less amplitude.

EXCELLENT (score 3): Hands follow the vertical jump in all phases, correct timing, intensity and amplitude.

Figure 1: Coordinated vertical jump classified as excellent (left) and non-coordinated vertical jump classified as poor (right).



Data Analysis

The data were analyzed using SPSS (version 22, IBM, USA) and Microsoft Excel (version 2013, Microsoft, USA) programs. Data are presented as means with standard deviation. There was no major deviation from normal distribution. Sex and age effects were tested with two-way Analysis of variance (ANOVA) with sex (2) as between factor and age (3) as within factor. Longitudinal changes were analyzed with repeated measures ANOVA, where improvement in jump performance of coordinated and non-coordinated jumpers was analyzed with repeated measures ANOVA and one fixed factor (jump coordination). The pooled longitudinal trends (our data and the data of others) were fitted by mathematical modelling using logarithmic curve to establish best fit. The Pearson correlation was used to analyze the correlation between fat mass and CMJ height. The level of significance for all tests was set at $P < .05$. If significance was confirmed, we reported also the η^2 effect size.

RESULTS

In all three-measurement points in total, 79 participants being included; their average body height, body mass, fat mass, muscle mass, CMJ height without arms, CMJ height with arms and percent of coordinated jumpers is shown in Table 1.

Table 1: Longitudinal anthropometric and jump performance data for both sexes.

Parameter	Sex	4 years	5 years	6 years	P _{sex} (η ²)	P _{age} (η ²)	P _{age x sex} (η ²)
Body height / cm	Boys	108±4.8	115±5.3	121±5.6	.073	<.001 (.943)	.339
	Girls	108±4.4	116±5.0	123±5.8			
Body mass / kg	Boys	18.2±2.5	20.5±3.0	23.6±3.7	.494	<.001 (.877)	.364
	Girls	18.5±2.8	21.3±3.6	24.0±4.2			
Fat mass / %	Boys	14.2±2.4	14.6±3.3	17.2±4.7	.001 (.133)	<.001 (.293)	.701
	Girls	16.7±2.5	17.1±3.8	19.2±4.2			
Muscle mass / kg	Boys	5.7±0.9	6.6±1.0	7.7±1.2	.002 (.116)	<.001 (.881)	.194
	Girls	5.1±0.8	6.0±0.9	6.9±1.1			
CMJ height without arms / cm	Boys	9.1±3.1	11.8±3.3	13.2±3.4	.337	<.001 (.620)	.072
	Girls	8.9±2.9	12.8±3.1	14.3±2.9			
CMJ height with arms / cm	Boys	9.9±3.3	12.6±3.2	14.7±3.3	.140	<.001 (.632)	.095
	Girls	8.9±2.9	14.2±3.7	15.8±3.2			
Coordinated jumpers / %	Boys	35	53	79		<.001 (.881)	
	Girls	33	76	87			

CMJ – countermovement jump
 Coordinated jumpers - subjects with excellent jumping coordination
 η² – partial eta-squared

Body height ($P < .001$; $\eta^2 = .943$) and body mass ($P < .001$; $\eta^2 = .877$) increased with age, similarly in both sexes. Post hoc analysis revealed that body height in boys increased for 7 % at the age of 5 ($P = .001$) and for 5 % at the age of 6 ($P = .001$) and in girls for 7 % at the age of 5 ($P = .001$) and for 5.5 % at the age of 6 ($P = .001$). Body mass increased in boys for 13 % at the age of 5 ($P = .001$) and for 15 % at the age of 6 ($P = .001$) and in girls for 15 % at the age of 5 ($P = .001$) and for 13 % at the age of 6 ($P = .001$).

Fat mass was higher in girls than in boys ($P = .001$; $\eta^2 = .133$) and increased with age ($P < .001$; $\eta^2 = .293$). Post hoc analysis revealed an increase only at the age of 6 in boys for 2.6 % ($P = .001$) and in girls for 2.1 % ($P = .001$). There was no correlation between CMJ height and fat mass at any age.

On the other hand, muscle mass was higher in boys than in girls ($P = .002$; $\eta^2 = .116$) and increased with age ($P < .001$; $\eta^2 = .881$). Post hoc analysis revealed an increase in muscle mass in boys for 16 % at the age of 5 ($P = .001$) and for 17 % at the age of 6 ($P = .001$) and in girls for 18 % at the age of 5 ($P = .001$) and for 15 % at the age of 6 ($P = .001$).

CMJ with ($P < .001$; $\eta^2 = .632$) and without the use of arms ($P < .001$; $\eta^2 = .620$) increased with age, similarly in both sexes. Post hoc analysis revealed an increase in CMJ without arms in boys for 23 % at the age of 5 ($P = .001$) and for 11 % at the age of 6 ($P = .001$) and in girls for 30 % at the age of 5 ($P = .001$) and for 10 % at the age of 6 ($P = .001$). CMJ with arms increased in boys for 16 % at the age of 5 ($P = .001$) and for 17 % at the age of 6 ($P = .001$) and in girls for 18 % at the age of 5 ($P = .001$) and for 15 % at the age of 6 ($P = .001$).

After putting together our data of CMJ with arms with the data of Focke et al. (2013), we modelled developmental trends of jumping performance (Figure 2). It is evident that the trends are logarithmic, where boys exceed jumping performance of girls after the age of 7.

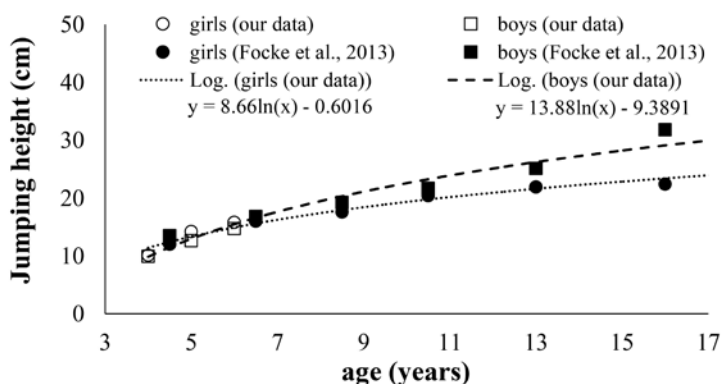


Figure 2: Comparison of counter-movement jumping height (with arms) analysed by the means of force plate in relation to age and gender from the literature.

In the next analysis we compared CMJ height performance (with arms) in children classified with different jumping coordination score (1 – poor; 2 – average; 3 – excellent). Table 2 presents the percentage of children performing excellent, average and poor jumping coordination for each age. We found that the percentage of average jumpers decreases with age by about half each year. On the contrary, we see that the percentage of excellent jumpers increased. The percentage on poor jumpers is diminishing, however at the age of 6 there are still 4.4 to 5.9 % of jumpers with poor coordination.

Table 2: Percentages of poor, average, and excellent jumping coordination classifications in relation to age and sex.

Arm coordination		4 years	5 years	6 years
Poor	Boys	11,8 %	14,7 %	5,9 %
	Girls	8,9 %	2,2 %	4,4 %
Average	Boys	73,5 %	35,3 %	14,7 %
	Girls	68,9 %	24,4 %	8,9 %
Excellent	Boys	14,7 %	50,0 %	79,4 %
	Girls	22,2 %	73,3 %	86,7 %

After the classification of CMJ coordination we compared average CMJ height (with arms) of children in each jumping coordination group, pooled for both sexes (Figure 3). Obviously, the children with excellent CMJ coordination progress more intensively than others, the average coordination jumpers still show progress, whereas the children with poor coordination do not progress at all.

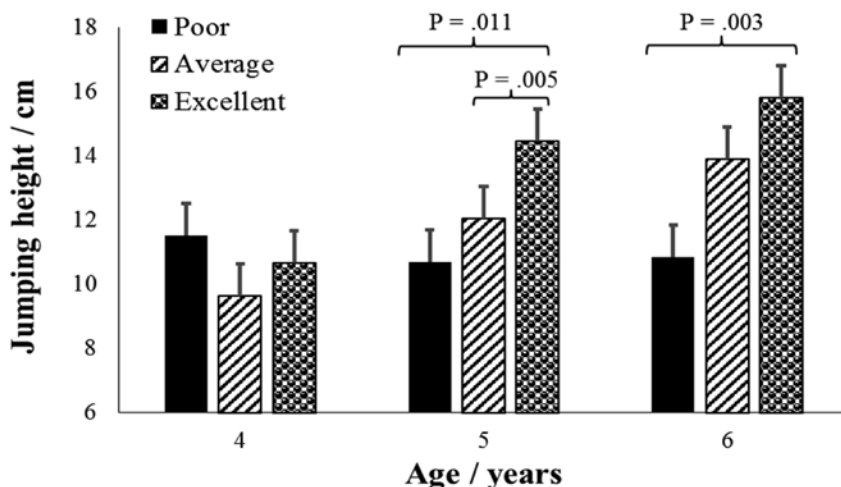


Figure 3: Age progress in counter-movement jumping height (with arms) of children from each jumping coordination (poor, average, excellent), pooled for both sexes.

DISCUSSION

Our longitudinal study contributed to new insights into children's FMS, focusing on vertical jumping. We developed a developmental trend for CMJ performance increase considering the arms use. We also extrapolated our data with the data of others (non-athletes, Focke et al., 2013) and modelled a logarithmic trend in jumping performance from the age of 3 to 16. Furthermore, we presented a strong dependence of jumping performance progress with jumping coordination.

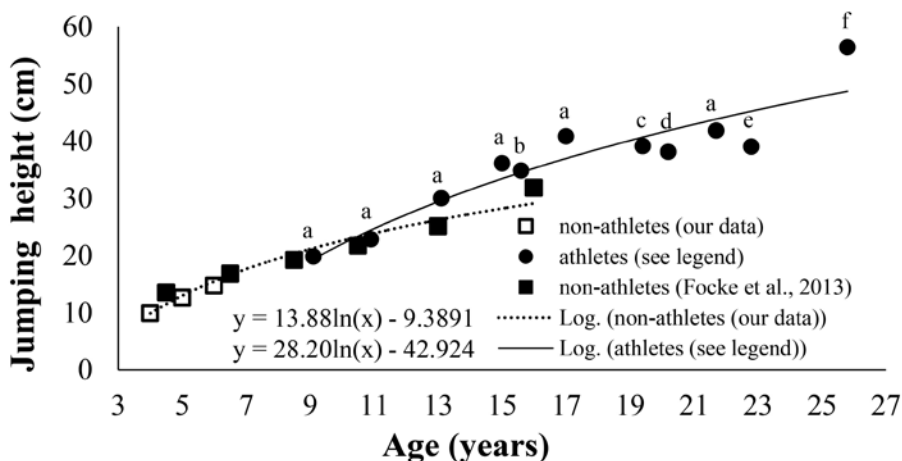
The CMJ is a commonly used method to measure leg or whole body explosive power (Richter, Jekauc, Woll, & Schwameder, 2010). Muscle composition, muscle mass and strength, body height, and jumping coordination are the most important factors of maximal jumping performance. However, at the age span of 4 to 6 we did not find any significant correlation between fat mass and CMJ height; however, we observed increasing fat mass when a child progresses from 4 to 6 years of age that is in accordance with the data of other studies (Weber, Leonard, & Zemel, 2012). It seems that increasing fat mass decreases the ability of anaerobic performance in adult population (Inacio, Dipietro, Visek, Miller, 2011), especially in adult athletes (Abidin & Adam, 2013).

From the observed CMJ height developmental trends we found significant year-to-year progress in both sexes for about 10 to 30 % per year, comparing the age of 5 (16 to 30 %) to age of 6 (10 to 17 %). The percentages of jumping progress strongly depen-

ding on lower average values at lower ages therefore might be misleading. However, later on the jumping performance increases in both sexes even more steeply after the age of 11, the boys preceding the girls at the age of 16 for about 8 to 10 %. The steeper progress at the age of 11s was found also in sprinting velocity of Slovenian children (Volmut, Pišot, & Šimunič, 2016), where girls show little improvement with age while boys continue to improve their sprinting velocity. The authors explained a vast portion of sprinting velocity improvement variance with regular organized sport exercise and contractile properties of skeletal muscles, in particular of biceps femoris, detected by Tensiomyography (Šimunič et al., 2011). Završnik et al. (2016) found significant sex differences in sprinting velocity after the age of 13 years, where boys have about 10 to 15 % higher sprinting velocity than girls. Završnik et al. (2016) also confirmed the importance of skeletal muscle contractile parameters for sprinting performance.

Focke et al. (2013) analyzed CMJ in 4- to 17-year-old children. Their data are inserted in Figure 2. They specified that boys jumped higher than girls and the difference was present in all age spans, being 12.5 % at the age of 4 to 5, 5 % at the age of 6 to 7, 9.1 % at the age of 8 to 9 years, 6.4 % at the age of 10 to 11, 14.6 % at the age of 12 to 14, and 42 % at the age of 15 to 17. The higher jump performance in boys is in line with the previously reported studies and can be explained by different gender-related physical conditions (Temfemo et al., 2009; Harrison & Gaffney, 2001). Although boys develop lower rate of force development than girls, boys jump higher than girls. It seems that the explosiveness obviously is not sufficient to guarantee better performance. However, boys are able to produce forces over a longer period of time leading to enhanced jumping height (Focke et al., 2013).

There have been numerous studies which have investigated jumping in athletes from various sports (Nikolaidis, Ingebrigtsen, Póvoas, Moss, & Torres-Luque, 2015; Yanci & Camara, 2016; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004; Cilli, Gelen, Yildiz, Saglam, & Camur, 2014; Sánchez-Muñoz et al., 2011). Apparently, at certain age they progress in jumping performance more steeply than non-athletes (Figure 4). From Figure 4 it is evident that the athletes older than 11 precedes non-athletes in the performance. Before that age there are actually no differences.



a – Nikolaidis et al. (2015); b – Sánchez-Muñoz et al. (2011); c – Pagaduan, Pojskić, Užičanin, and Babajić (2012); d – Cilli et al. (2014); e – Yanci and Camara (2016); f – Wisløff et al. (2004).

Figure 4: Comparison of countermovement jumping height (with arms) of boys in relation to age and sport participation.

We have also presented the effect of arm swings coordination on jump performance. This has been also a focus of other studies, but in adult population (Payne, Slater, & Telford, 1968; Miller, 1976; Shetty & Etnyre, 1989; Harman et al., 1990). In the vertical jump, as well as in many other sports skills, the arms are swung vigorously upwards during the take-off to enhance performance (Lees, Vanrenterghem, & Clercq, 2004). The arm swing can increase the ground reaction force in the latter half of the propulsive phase, leading to enhanced net ground reaction impulse. Consequently, the center of mass position and vertical velocity at the take-off can also be raised, which increases the jump height (Cheng, 2008). Feltner, Bishop and Perez (2004) showed that the arm swing decreases extensor joint torques early in the propulsive phase but augments these same extensor torques later in the propulsive phase. The increased jump height consists of increased center of mass height (54 %) and vertical velocity (46 %) at the take-off, while a different percentage distribution (28 % and 72 %, respectively) was found by Lees et al. (2004). Hara, Shibayama, Takeshita and Fukashiro (2006) studied the effect of the arm swing on lower extremities in vertical jumping. They concluded that an increased jump height is mainly due to increased work done by the lower extremities, which also comes as a result of the additional load on the lower extremities because of the arm swing. Although an increased take-off velocity is reported consistently when

arms are swung, the mechanisms by which arm swing leads to an increase in the take-off velocity have not been fully established (Lees et al., 2004; Harman et al., 1990; Shetty & Etnyre, 1989).

Proper use of the arms assures the optimal use of stretch shortening cycle, where Harrison and Gaffney (2001) found that 6 year-old children could utilize the SSC in vertical jumping equally well compared to adults. Harrison and Moroney (2007) found also that girls at age $6.6 \pm .5$ years appear to be equally effective to adult woman aged 22.1 ± 1.2 years in using the arms to improve jumping performance. Moreover, results indicated that the arm action significantly improved performance in both adults (woman) and children (girls) and adults jumped significantly higher than children irrespective of whether arm action was used. Improvements in performance of the jump may be due more to differences in body stature and muscle strength and power rather than coordination and control (Harrison & Moroney, 2007).

Study Limitations

The limitations of the study are in the selection of the research environment, namely only one Slovenian region was selected for performing this study. Furthermore, there are no objective data of their physical status or habits available for the whole group of participants.

CONCLUSION

This research focused on studying 4 to 6 year-old children's FMS, vertical jump. We found no sex differences, but confirmed age-related CMJ height increase as well as strong dependence of CMJ height increase with engaged jumping coordination. We conclude that jumping coordination is the most important factor of jumping performance in the studied age span.

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