

## Vertical jump development in elite adolescent volleyball players: Effects of sex and age

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**Background:** Vertical jump is one of the most prevalent activities performed in volleyball. During adolescence, boys and girls undergo substantial changes in physiological and anthropometric characteristics that influence vertical jump performance. **Objective:** The purpose of this study was to examine and quantify sex and age-related differences in vertical jump performance assessed as vertical jumps height (VJH) and ground contact time ( $T_c$ ) during repeated vertical jump tests within the Czech and Slovak population of elite adolescent volleyball players. Further aims were to compare the obtained results to non-athletic adolescent national normative data and investigate the relationship between basic anthropometric measures and VJH. **Methods:** The cross-sectional study was conducted on 203 females and 180 males from 13 to 19 years old. Statistical analysis of VJH differences between sex and age categories was performed using two-way ANOVA with Tukey's post hoc test. The relationship between basic anthropometric parameters and VJH were examined by Pearson's correlation analysis. **Results:** ANOVA showed statistically significant differences in VJH between males and females ( $p < .001$ ) and across the age categories ( $p < .001$ ). Males performed better than females in each age group and VJH increased along with age. For females VJH reached a plateau at the age of 14 and then stagnated. Male players have lower  $T_c$  than females ( $p < .05$ ), although age did not show significant influence on  $T_c$  in either females or males ( $p > .05$ ). Volleyball players have significantly higher VJH than non-athletes across all age categories and sex differences in volleyball players were smaller than the sex differences among non-athletic adolescents. A correlation analysis revealed only weak sex specific correlations of VJH with body height, body mass and BMI. **Conclusions:** The presented study showed significant sex differences in VJH between elite male and female volleyball players from the age of 15. VJH increases continually with increasing age in males. In females the effect of age on VJH was insignificant.

**Keywords:** volleyball, vertical jump height, ground contact time, adolescents, anthropometry

### Introduction

Volleyball is a high-intensity team sport based on short and frequent explosive activities such as jumping, diving, and ball play (Sheppard, Nolan, & Newton, 2012). Besides the technical and tactical skills, well-developed speed, agility, and muscular power are required for high-level volleyball performance (Nikolaidis, Ziv, Arnon, & Lidor, 2012; Sheppard, Gabbett, & Stanganelli, 2009). Regarding anthropometric profiles, great height, lean body mass, and low-fat percentage seem to

be prerequisites of high-level volleyball players (Nikolaidis, Afonso, & Busko, 2015). Several studies have related optimized performance in volleyball to a well-developed and durable jumping ability (Sattler, Hadžić, Dervišević, & Markovic, 2015; Sheppard et al., 2009). Players with strong vertical jump performance are able to get higher above the net for spiking and scoring as well as in defensive play for blocking. Jumping can also influence serving by producing more dynamic hits and power (Matušov, Zapletalová, Duchoslav, & Hagara, 2013). Therefore, vertical jump ability belongs to the elements that strength and conditioning programs aim to improve (Lehnert et al., 2012). Vertical jump involves a highly coordinated sequence of events comprising nearly all neuro-muscular parts of lower extremities, whereupon many factors such as jumping

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technique, balance, muscular power production, and anthropometric characteristics are proven to contribute to the performance in vertical jump (Sheppard et al., 2008).

Besides the physiological and anthropometrical factors, sex and age also play a significant role in the vertical jump (Doré et al., 2005). During adolescence, marked changes in human physiology occur due to muscular, neuronal and hormonal factors (Roemmich & Rogol, 1995). With puberty, males usually become larger in skeletal length, width and in muscle size, but smaller in relative fat mass compared to females (Seger & Thorstensson, 2000). However, the observed jumping performance progress remains problematic to assess since the concurrent contribution of anthropometric changes in biological maturation and physical exercise during growth in boys and girls (Martin et al., 2004). Normative data for English school children aged 10–15 years have shown that jump height increases significantly year on year for boys. For girls, jump height reaches a plateau after the age of 12 (Taylor, Cohen, Voss, & Sandercock, 2010). Sex specific normative paediatric data in Caucasian children and adolescents aged 6–19 years have presented that both maximum peak power and maximum force of jumping were strongly dependent on age and weight in both sexes. Both parameters steadily increased in boys and plateaued in girls aged >13 years (Sumnik et al., 2013). A physical fitness population study of European adolescents revealed normative data for a battery of 10 fitness tests including squat jumps, counter movement jumps and Abalakov jumps with the same trend regarding the sex and age (Ortega et al., 2011).

All of the above mentioned studies reported normative data of the non-athletic population which suggests that they are apparently not influenced by regular sport training. Many of the changes associated with regular training, although not all, go in the same direction as those that follow normal growth and maturation. It is difficult to partition training effects from those of normal growth and maturation in the available data (Naughton, Farpour-Lambert, Carlson, Bradney, & Van Praagh, 2000). Studies monitoring sex and age specific development in the motor abilities in the athletic adolescent population are less reported. Short-term longitudinal studies of male and female athletes in a variety of sports indicate growth rates within the range expected for non-athletes (Malina, 1998). Progression differences as a function of age and sex were identified in running and jumping events in Norwegian adolescent track and field athletes. The study highlighted that performance improvement during puberty is considerable depending on the sport discipline (Gallová, Doležalová, Lednický, Matulaitis, & Bračić, 2015;

Tonnessen, Svendsen, Olsen, Guttormsen, & Haugen, 2015). Therefore, the main purpose of our research was to investigate the effect of sex and age on vertical jump development in elite adolescent volleyball players. In many sports like volleyball and basketball, a jump needs to be high enough but also not take too long to execute, otherwise the opportunity to intercept the ball may be missed (Domire & Challis, 2015). Vertical jump height (VJH) is strongly related to the maximum strength of an athlete, whereas ground contact time ( $T_c$ ) characterizes dynamic explosive vertical jump capacity (Philips & Flanagan, 2015; Thomas, Kyriakidou, Dos'Santos, & Jones, 2017). Therefore the vertical jump development was assessed during repeated vertical jump test as VJH with further analysis of  $T_c$  in each sex and age category. Moreover, it was aimed to investigate the relationship between anthropometric parameters and VJH.

## Methods

### Participants' characteristics

The presented cross-sectional study assessed 383 adolescent athletes, 203 females and 180 males from Czech and Slovak volleyball teams playing the 1st or 2nd national divisions. The ages of participants ranged from 13 to 19 years with the mean age of  $16.0 \pm 1.6$ . Written informed consent was obtained from all parents and/or responsible adults. The measurements were performed according to the ethical standards of Helsinki Declaration. The study protocol was approved by Ethics Committee of Faculty of Physical Education and Sports of Comenius University in Bratislava. Basic anthropometric measurements, including standing body height (BH), body mass (BM) were used to determine the body mass index (BMI) of each participant. BM (kg) was measured on an electronic scale to the nearest 0.1 kg, with a scale of 150 kg. Standing BH (cm) was determined to the nearest 0.1 cm using a stadiometer. BMI was calculated using BM divided by BH squared ( $\text{kg}/\text{m}^2$ ).

### Vertical jump testing

Participants of the study trained in various sport clubs spread across the Czech Republic and Slovak Republic, therefore we used an easily portable device, the FiTRO Jumper contact jump mat (FiTRONiC Diagnostic and Training Systems LTD, Bratislava, Slovakia) to assess VJH. The population norms of physical fitness in non-athletic adolescents measured previously have used the same device for VJH assessment (Moravec, Kampmiller, & Sedláček, 2002). The subjects performed a 10 seconds repeated vertical jump test. The starting position was a straddle standing with hands on hips

in order to minimize the influence of the arms on the jump. After the initial hop, a 10 seconds repeated jump test was performed. During the jump, the trunk had to remain “as vertical as possible” to limit its influence on the performance and with the knees “as straight as possible” during the contact and flight phase (knee angle around 180 degrees, foot is in extension). The subjects performed 2 trials of the repeated jump test. If the participant jumped out of the jumping mat, the test was repeated. During both trials the subjects were instructed to jump “as high as possible”. Rest intervals between trials were approximately 60 seconds. The average height and average  $T_c$  of the three best attempts were taken into account for further analysis.

### Statistical analysis

Descriptive statistics presented as means and standard deviations were calculated for male and female groups as a whole and sex-specific single year age groups. A Kolmogorov-Smirnov test ( $p = .367$ ) was used to test all data for normality and Levene’s test ( $p = .188$ ) was used to test the homogeneity of variance. A two-way ANOVA design was applied to determine whether there were any significant main effects of age (13, 14, 15, 16, 17, 18, or 19 years) or sex (female or male). Tukey’s HSD post-hoc procedures were used to examine where significant effects occurred. Partial eta squared ( $\eta_p^2$ ) was calculated as a measure of effect size. Value of .01 was considered as a small effect, .06 as a moderate effect and .14 above as a large effect. The association of VJH to anthropometric parameters was examined by using Pearson’s correlation coefficient  $r$ . Correlation was considered as trivial ( $r < .2$ ), weak ( $.2 < r \leq .4$ ), moderate ( $.4 < r \leq .6$ ), strong ( $.6 < r \leq .8$ ), and very strong ( $.8 < r \leq 1$ ) (Hopkins, Marshall, Batterham, & Hanin, 2009). All analyses were carried out using SAS (Version

9.2; SAS Institute, Cary, NC, USA) and Excel software (Version 2013; Microsoft, Redmond, WA, USA).

## Results

### Participants’ characteristics

Anthropometric data of BM, BH, BMI in 203 female and 180 male adolescent volleyball players are presented in Table 1. Significant differences between females and males were found for BM ( $p < .001$ ) after 15 years of age and BH ( $p < .001$ ) in all age categories. The BMI did not differ significantly between the female and male groups.

### Differences in VJH and $T_c$ in adolescent volleyball players by sex and age

Table 2 displays the VJH and  $T_c$  data measured in adolescent volleyball players according to sex and age. ANOVA revealed that sex ( $F(1, 382) = 108.08$ ,  $p < .001$ ,  $\eta_p^2 = .068$ ) and age ( $F(6, 376) = 7.55$ ,  $p < .001$ ,  $\eta_p^2 = .03$ ) has a statistically significant effect on VJH. The post hoc analysis showed that there were no significant sex differences until the age of 15. From the age of 15 males perform significantly better than females ( $p < .001$ ) with moderate effect size. In males VJH increases continually with increasing age ( $p < .001$ ) with small effect size. There were no significant differences in VJH in females across all age categories.

Analysis of  $T_c$  data revealed that only sex has significant effect on  $T_c$  ( $F(1, 382) = 5.26$ ,  $p = .031$ ,  $\eta_p^2 = .006$ ). The post hoc analysis showed that there were no significant sex differences until the age of 16. From the age of 16 males perform significantly better than females ( $p < .05$ ) with small effect size. The analysis did not prove significant influence of age on  $T_c$  in either females or males ( $F(6, 376) = 1.80$ ,  $p = .074$ ).

Table 1

*The numbers of participants and anthropometric characteristics (presented as mean  $\pm$  SD) in adolescent volleyball players by sex and age*

Age	<i>n</i>		Body mass (kg)		Body height (cm)		Body mass index (kg/m <sup>2</sup> )	
	Female	Male	Female	Male	Female	Male	Female	Male
13	11	16	55.1 $\pm$ 6.5	54.8 $\pm$ 9.3	173.3 $\pm$ 4.9	168.5 $\pm$ 7.0**	18.5 $\pm$ 1.8	19.3 $\pm$ 2.0
14	37	17	61.9 $\pm$ 6.7	69.5 $\pm$ 9.8*	176.4 $\pm$ 5.9	183.9 $\pm$ 7.3**	19.8 $\pm$ 1.6	20.5 $\pm$ 2.2
15	52	26	65.0 $\pm$ 6.7	72.9 $\pm$ 7.1**	177.8 $\pm$ 4.7	187.4 $\pm$ 6.5**	20.5 $\pm$ 1.7	20.7 $\pm$ 1.6
16	26	47	68.8 $\pm$ 6.5	74.7 $\pm$ 9.4**	180.0 $\pm$ 6.1	188.1 $\pm$ 8.2**	21.2 $\pm$ 1.4	21.0 $\pm$ 1.5
17	46	34	70.9 $\pm$ 7.1	77.8 $\pm$ 7.5**	179.7 $\pm$ 5.3	189.2 $\pm$ 6.6**	21.9 $\pm$ 1.7	21.7 $\pm$ 1.6
18	20	19	72.3 $\pm$ 7.8	82.0 $\pm$ 6.3**	180.4 $\pm$ 4.7	191.5 $\pm$ 4.5**	22.2 $\pm$ 2.1	22.4 $\pm$ 1.7
19	11	21	68.0 $\pm$ 8.5	84.2 $\pm$ 5.5**	178.2 $\pm$ 4.8	192.1 $\pm$ 5.8**	21.6 $\pm$ 1.8	22.8 $\pm$ 1.0

*Note.* Asterisks indicate a statistically significant difference between females and males in the same age category (\* $p < .05$ , \*\* $p < .001$ ).

Table 2

Vertical jump height (VJH) and ground contact time ( $T_c$ ) in adolescent volleyball players by sex and age. Values are presented as mean  $\pm$  SD.

Age	VJH (cm)		$T_c$ (s)	
	Female	Male	Female	Male
13	30.4 $\pm$ 2.7	30.1 $\pm$ 4.1	0.181 $\pm$ 0.017	0.179 $\pm$ 0.027
14	32.2 $\pm$ 4.9	31.8 $\pm$ 3.9	0.189 $\pm$ 0.024	0.185 $\pm$ 0.024
15	32.1 $\pm$ 3.4	35.9 $\pm$ 4.1**	0.182 $\pm$ 0.020	0.179 $\pm$ 0.017
16	30.6 $\pm$ 4.0	37.2 $\pm$ 4.8***	0.190 $\pm$ 0.025	0.183 $\pm$ 0.015*
17	30.8 $\pm$ 4.5	39.4 $\pm$ 4.3***	0.194 $\pm$ 0.020	0.187 $\pm$ 0.015*
18	31.0 $\pm$ 3.8	40.1 $\pm$ 4.9***	0.196 $\pm$ 0.023	0.189 $\pm$ 0.016*
19	31.4 $\pm$ 2.4	41.3 $\pm$ 5.8***	0.195 $\pm$ 0.025	0.182 $\pm$ 0.018**

Note. Asterisks indicate a statistically significant difference in post-hoc analysis between females and males in the same age category (\* $p$  < .05, \*\* $p$  < .01, \*\*\* $p$  < .001).

### Relationship between anthropometric parameters and VJH in adolescent volleyball players

From 14 years onward BM increased with age in both sexes. BH continuously increased with age in males whereas in females, BH reached its maximum at the age of 16 and remained stabilized. A correlation analysis between BM, BH, BMI and VJH revealed only trivial to weak sex-specific correlations in adolescent volleyball players. In females only weak negative correlation of VJH with BM ( $r = -.22$ ,  $p = .043$ ) was observed. In contrast in males, weak correlations of VJH with BM ( $r = .28$ ,  $p = .035$ ), BH ( $r = .24$ ,  $p = .042$ ) and BMI ( $r = .28$ ,  $p = .035$ ) were identified.

### Discussion

Considering the sex differences, after the age of 15 males performed better than the females in each age group. Furthermore, VJH in males was improved significantly with increasing age, while for females VJH reached a plateau at the age of 14 and then stagnated. Male volleyball players improved VJH with advancing age and accelerating gain was detected between 14–15 years of age. The sex differences and significantly better VJH scoring in males could be explained by the general increase in muscle mass connected with the increase of body height, which favored the males from the age of 14 years onwards (Laffaye, Choukou, Benguigui, & Padulo, 2016; Lidor & Ziv, 2010). Together with the morphological differences during maturation, mainly the increase of testosterone levels in males induces selective hypertrophy of type II muscle fibers influencing the explosive strength abilities (Metaxas et al, 2014). This result is consistent with earlier reports of jump performance depending on the muscle force in both athletic and non-athletic adolescents (Davis,

Briscoe, Markowski, Saville, & Taylor, 2003). The difference in VJH between males and females is also related to the body fat percentage which is negatively associated to the jump height (Davis et al., 2003). Besides the overall lower VJH score than males, the female athletes reached their maximum at the age of 14, which was followed by stagnation or even the decline of VJP with increasing age. This trend in VJP was also observed in other studies of athletics as well as non-athletic adolescent populations (Ortega et al., 2011). A comparison of VJH between adolescent volleyball players and non-athletes in Slovak population (Moravec et al., 2002) revealed similar trends with regard to age and sex. However, in volleyball players, higher annual enhancement of VJH in each age category was observed comparing to non-athletes. The different sex related development of VJH across ages could be explained by the earlier termination of growth in females and divergent effect of estrogen and testosterone on skeletal muscle. The growth spurt in females occurs approximately 2 years earlier than in males and plateaus at 15–16 years of age, whereas males' growth spurts continue up to the age of 19–20 years (Tanner, Whitehouse, Marubini, & Resele, 1976). Analysis of  $T_c$  as an assessment of dynamic explosive vertical jump capacity revealed unchanged values across all age categories in females as well in males. However, the male players have significantly lower  $T_c$  than females after 16 years of age.

In the context of anthropometric parameters, BM, BH and BMI increased with age in both male and female volleyball player groups. A significant sex difference was found for BM and BH between males and females in each age category after the age of 14. Surprisingly, there were no significant differences in BMI in any age category. A correlation analysis in volleyball players

indicated only a weak negative correlation of BM with VJH in females, unlike in males, where weak correlations of BM, BH and BMI with VJH were observed. These results are in line with previously reported findings. A study of the relationship between VJH and BM revealed that VJH is independent on BM (Markovic & Jaric, 2007). Similarly, BH showed no significant effect on vertical jump among sub-elite athletes (Aslan, Koç, Aslan, & Özer, 2011). Davis et al. (2003) reported that the body fat percentage is negatively associated to the VJH and that there is no significant relationship between vertical jump and BH among recreational athletes. Although the above mentioned biological differences probably explain a large part of the pronounced sex and age differences, the much higher VJH scores of adolescent volleyball players than non-athletes reflect regular exercise training. The stagnation of VJH in female volleyball players after the age of 14 was not eliminated by regular exercise and may point to the differences in the training systems of male and female junior Czech and Slovak volleyball players. In male teams there is a strict chronological age differentiation. Training methods gradually and systematically develop fitness together with volleyball-specific skills. In contrast, female teams are age inconsistent and oriented on emphasizing game specific performance without adequate training to improve power and strength.

A limitation of our study was that we were not able to control the volume and intensity of strength training programs in volleyball teams.

## Conclusions

The presented cross-sectional study of elite adolescent volleyball players showed that there were no significant sex differences in VJH between the elite male and female volleyball players until the age of 15. From the age of 15 males jump significantly higher than females. In males VJH increases continually with increasing age however, in females no significant differences between all age categories were found. BM, BH and BMI did not significantly influence VJH in elite adolescent volleyball players.

Based on the expertise and knowledge of the system of long-term player development in the Slovak Republic and Czech Republic, a different trend of VJH in relation to age between the male and female volleyball players could be explained by natural physiological factors during growth and maturation.

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## Conflict of interest

There were no conflicts of interest.

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