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SPECIFIC ISSUES OF VERTICAL JUMPS AS FUNDAMENTAL PERFORMANCE DIAGNOSTICS TOOLS

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Vertical jumping ability is an important factor in many sports. Therefore, the performance diagnostics with counter-movement jumps (CMJ) and drop jumps (DJ) became a fundamental tool to measure explosive leg power. Both jumps have been frequently assessed in various subject groups. However, most previous studies involved adult male participants, who were experienced in jumping, and data from younger subjects with less jumping experience is rare. Therefore, the focus at first was to set on the analysis of CMJ and DJ performance in children and adolescents of different age, gender and activity level in general. Furthermore, specific aspects of arm-swing in CMJ are investigated in good and poor jumpers to compare kinematic and kinetic parameters of selected joints, and inter-joint coordination of different joints between groups and CMJ with and without arm-swing.

KEY WORDS: counter-movement jump, drop jump, arm-swing.

INTRODUCTION: In many sports including athletics, volleyball and basketball, vertical jumping ability is an important and performance limiting factor that is directly related to the athlete's ability to produce high leg power. The measurement of leg power is a fundamental tool in biomechanical performance diagnostics and counter-movement jump (CMJ) and drop jump (DJ) are commonly used methods in this field (Bissas & Havenetidis, 2008; Frick et al., 1991; Thomas et al., 2009). Despite the considerable body of scientific knowledge currently available on the biomechanics of jumping (Feltner et al., 2004; Lees et al., 2004), still little is known about the application of the two jumping techniques in performance diagnostics for children and adolescents with respect to their activity level. This research initially examines the application of the vertical jump (VJ) in new areas of human performance, with a specific focus on limitations of CMJ jump as a performance diagnostics. Secondly an investigation of DJ in children and adolescents was performed. Finally, the influence of arm-swing during CMJ on the kinetics, kinematics and joint coupling is explained.

COUNTER-MOVEMENT JUMP IN CHILDREN AND ADOLESCENTS: CMJ data of a large population during childhood and adolescence including boys and girls as well as active and non-active subjects is rare, but could present an insight into the development of jumping ability in different subject groups. By the implication of multiple parameters and their variability, information about the stability of the testing procedure and limitations of its application in different age, gender and activity groups can be provided. Therefore, the CMJ performance of 1835 children and adolescents of different gender and activity level, aged between 4 and 17 years, was tested on a force platform. Jump height (body heights, BH), maximum vertical force (body weight, BW) and maximum rate of force development (BW/s) as well as its variability over three trials were calculated. Main results of age and gender are shown in Figures 1, 2 and 3. With increasing age jump height increased significantly in boys compared to girls, maximum force did not show significant changes and maximum rate of force development significantly decreased. The variability of jump height and maximum force decreased significantly with increasing age, indicating a lower level of variability from the age of ten years onwards. Only the variability of the maximum rate of force development was very high for both genders and all age groups. Activity level only affected jump height and its variability. Compared to non-active subjects jump height was significantly higher and its variability was significantly smaller in active participants. It can be concluded that the CMJ is an applicable test in performance diagnostics for children and adolescents. Jump height is the most stable and meaningful parameter to describe developmental changes in jumping performance of children and adolescents, specifically at the age of ten years onwards. Maximum rate of force development showed least stable results and should be interpreted with caution. For the interpretation of jumping performance data in children and adolescence the sport activity level has to be considered as it affects jumping performance and might lead to different results.

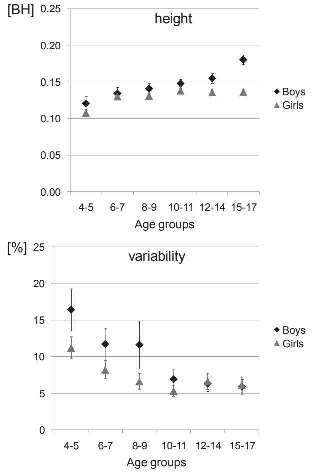

Figure 1: Jump height and its variability by age and gender (mean±CI_{95})

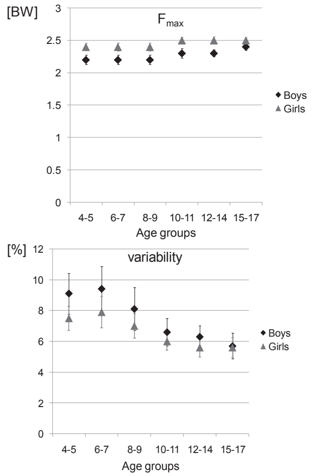

Figure 2: Maximum force (F_{max}) and its variability by age and gender (mean±CI_{95})

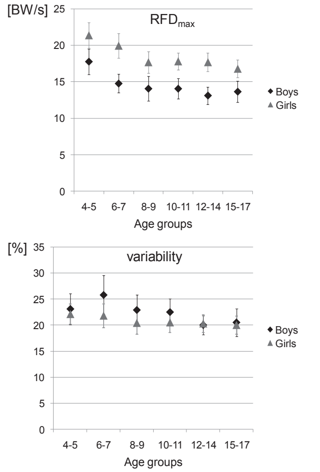

Figure 3: Maximum rate of force development (RFD_{max}) and its variability by age and gender (mean±CI_{95})

DROP JUMP IN CHILDREN AND ADOLESCENTS: Compared to the CMJ the DJ represents a more complex movement. Due to the short contact times, high energy has to be absorbed by high muscle stiffness and strength. Therefore, high leg power is required to perform a correct DJ without heel contact. Many studies do not seem to control for correct technique hence contact times longer than 200-250 ms and double peaks in the force-time curves are reported, even for adult experienced subjects (Byrne & Eston, 2002; Laffaye et al., 2006). Despite this high muscular requirement many studies use the DJ as performance diagnostics tools with children and adolescents without minding correct jumping techniques with appropriate contact times (Bencke et al., 2002; Hewett et al., 2006; Kollath et al., 2006; Oliver et al., 2008; Quatman et al., 2006). Based on these previous studies, the aim of this research was to examine whether the DJ is a valid and sensitive method for the measurement of explosive leg power in children and adolescents. A total of 466 children of different age, gender and activity level performed two DJ (20 cm) on a force plate. Contact time, jump height, maximum force (body weight, BW) and maximum rate of force development (BW/s) were calculated. For the current study an inclusion criterion for jump trials was based on contact times less than 210 ms. Following inclusion reactive strength index (jump height [cm]/contact time [s]) was calculated to identify the best trial, which was subsequently used for further analysis. Nearly 70% of all subjects were not able to perform a correct DJ as they showed contact times higher than 210 ms and double peaks in the force time curves. For the remaining 146 subjects age and gender significantly affected jump height (Figures 4, 5 and 6), but not maximum force and maximum rate of force development. In contrast the activity level affected all three parameters. Jump height, maximum force and maximum rate of force development increased with increasing activity level. In conclusion it can be stated that most of the children aged between 10 and 18 years did not have the muscular preconditions to perform a DJ correctly. The older and the more active children performed the best DJ with short contact times and good results in jump height. Thus, DJ should only be applied in performance diagnostics with subjects of high activity level and with sufficient experience in reactive strength exercises.

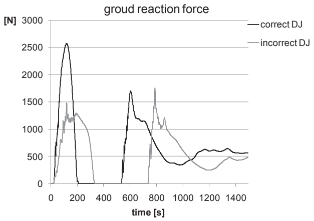

Figure 4: Force time curve of a correct (black) and an incorrect (grey) drop jump

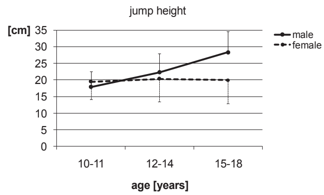

Figure 5: Jump height of drop jumps by age and gender (mean±s)

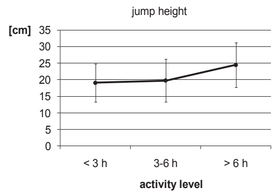

Figure 6: Jump height of drop jumps by activity level (mean±s)

ARM-SWING IN COUNTER-MOVEMENT JUMPS: Specifically for the CMJ two different jumping techniques are used in the field: CMJ with bilateral arm-swing (CMJA) and CMJ with arms akimbo (CMJ). Several studies comparing these two techniques have shown that the arm-swing increases jump height by 10–20%. The mechanisms by which the arm-swing leads to increased jump height seem to be well understood (Feltner et al.; 1999, Lees et al., 2004). However, arm-swing can be more or less effective. Few studies show differences between the benefit of the arm-swing between skilled and unskilled jumpers and between subject groups of different activity levels (Laffaye et al. 2006; Richter et al., in press). These studies, however, only concluded that there are interactions between the jumping technique and the activity level, but they don't address the detailed mechanisms that lead to the better benefit of arm-swing for the skilled or active subjects compared to unskilled, sedentary participants. Single joint kinematics, kinetics and joint coupling (continuous relative phase; Hamill et al., 1999) was used to examine differences between CMJ with and without arms-swing for 27 male subjects. According to their jump height they were divided in two groups: good (group I) and poor jumpers (group II). Similar to Laffaye et al. (2006) and Richter et al. (in press) a significant interaction between jumping technique and subject group was found for the jump height indicating a higher benefit of arm-swing for good jumpers compared to their weaker counterparts (Figure 7). For selected kinematic and kinetic parameters of the joints of the lower extremity as well as for the mean absolute relative phases between hip and knee, knee and ankle and shoulder and knee (Figure 8) no interactions between jumping technique and subject group were found. Only for the shoulder angular velocity significant interactions could be revealed showing significant higher velocities for the upward movement of the arms and significant lower values for the downward velocity at the end of the movement for group I compared to group II (Figure 7). It can be concluded that the greater benefit of arm-swing for the good jumpers cannot be explained by different coordination patterns between the joints but by a faster forward arm-swing and an abrupt deceleration of the arms at the end of the jump enhancing the energy transfer from the arms to the trunk and the rest of the body, respectively.

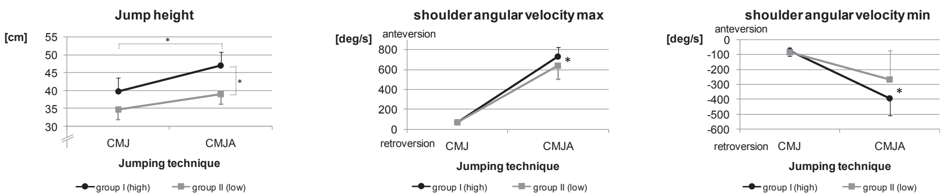

Figure 7: Jump height, maximum shoulder angular velocity and minimum shoulder angular velocity of counter-movement jump with arms akimbo (CMJ) and with arm-swing (CMJA) in group I (good) and group II (poor) (mean±s)

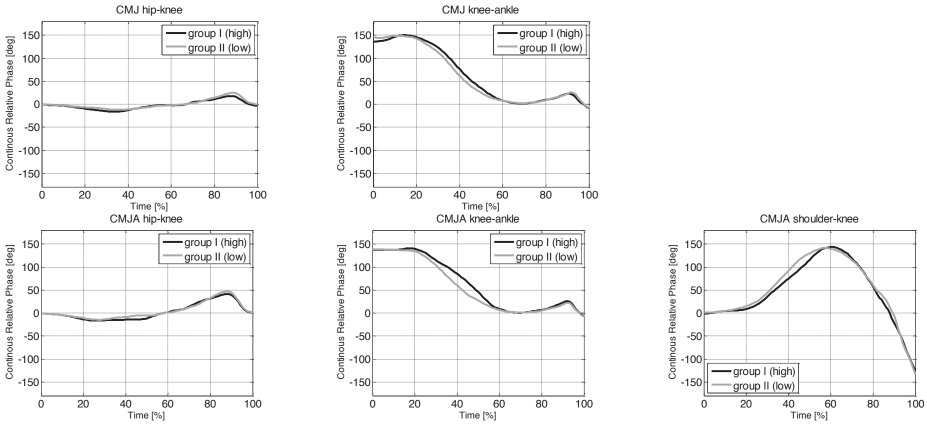

Figure 8: The ensemble average relative phase angles of hip-knee, knee-ankle and shoulder-knee for counter-movement jump with arms akimbo (CMJ) and with arm-swing (CMJA) for group I (good) and group II (poor) separately (0°=in-phase; ±180°=anti-phase)

CONCLUSION: This research has shown that the VJ is a useful diagnostics tool in the assessment of performance. Additionally the influence of activity level and experience should be accounted for when interpreting these data. It was also shown that an effective arm-swing can mainly be attributed to a faster forward arm-swing and an abrupt deceleration of the arms at the end of the jump.

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