

JUMPING PERFORMANCE AND LOWER LIMB KINEMATIC ANALYSIS AMONG CHILDREN WITH DOWN SYNDROME

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Abstract

This study investigated the jumping performance and lower limbs kinematics among boys with Down syndrome. The participants ($n = 23$) were required to perform standing broad jump test and their jumping performance was evaluated using Motor Skills Inventory for locomotor skills analysis. In addition, the jumping performance was also recorded for lower limb kinematic analysis using 2-Dimensional video recording tools. Results revealed that 91.3% of the participants scored 'Poor' values of standing broad jump distances. Based on the Motor Skills Inventory analysis, five participants were grouped as 'Rudimentary', nine participants were 'Functional' and the other nine participants were 'Mature' level of motor development. Based on these three groups, further analysis was conducted on the lower limbs kinematics during jumping performance (three phases: take off, jump peak height and landing). Finding showed that there were no significant differences on lower limb kinematics between the groups during these three phases of jumping. Proper intervention strategies are needed in order to improve the jumping skills among children with Down syndrome.

Introduction

Delay in motor development among children with Down syndrome (DS) lead to slow rate acquisition of fundamental movement skills among them compare to typically developing peers (Gallahue, Ozmun, & Goodway, 2006). It also associated with impairments in musculoskeletal system, central nervous system and cardiovascular system. The joint hyperextensibility, muscle hypotonia (Capiro & Rotor, 2010; Wang & Ju, 2002), poor hip abductors and knee extensor (Gupta, Rao, & Sd, 2011) were demonstrated as the causes of the delay. Uncoordinated movement (Uyanik, Bumin, & Kayihan, 2003), poor postural control and strength proficiency impaired their motor development (Gupta et al., 2011). These hypotonic muscles signified the importance of lower limb muscular strength in fundamental movement skill of jumping (Capiro & Rotor, 2010; Castro-Piñero et al., 2010; Gallahue et al., 2006; Gupta et al., 2011; Wang & Ju, 2002). Jumping performance such as horizontal jump intervenes the delayed motor proficiency faced by children with DS (Gupta et al., 2011).

Keywords: Children with Down Syndrome, Biomechanics, Jumping Performance, Kinematic Analysis, Motor Development, Motor Learning.

The criterion-related validity and reliability of horizontal jump as the fitness test of lower limb muscular strength among children with and without DS had been proven by previous studies (Fernandez-Santos, Ruiz, Cohen, Gonzalez-Montesinos, & Castro-Piñero, 2015; Hardy, Merom, Thomas, & Peralta, 2018; Lejčarova, 2008). Horizontal jump analyses the movement proficiency component of strength, coordination, and balance, which were fundamental in deterring the postural alignment and hypotonic primary synergies in children with DS (Malak, Kostiukow, Krawczyk-Wasielewska, Mojs, & Samborski, 2015). The locomotors skill of horizontal jumping performance signify the importance of fundamental motor skill proficiency as foundation for development of more advanced and specific motor skills (Gallahue et al., 2006). The movement pattern is analysed qualitatively as the developmental jumping movement (Wang & Ju, 2002) as the progression of the motor development is concerned. The biomechanical analysis studied the horizontal jump through four basic phases in determining its performance score of horizontal distance, from scientific point of view: preparation phase, take-off phase, flight phase, and landing phase (Hraski, Hraski, Mraković, & Horvat, 2015).

Kinematic study on the motor development are fundamental with reference to progression of motor learning model (Chow, Koh, Davids, Button, & Rein, 2014). The cinematography analysis determines the coordination pattern of a multi-articular action of body segments and joints in mastering the underlying processes of movement coordination acquisition of jumping movement for example (Chow et al., 2014; Hraski et al., 2015). In the motor proficiency of horizontal jump, the participant could perform greater distance with the generated force from the increased involvement of motor system degrees of freedom at relevant joints (Chow et al., 2014) and body segments (Hraski et al., 2015) during the jumping phases. Therefore, by exploring the kinematic variable of lower limb joint range of motion (ROM), the conditioning motor development of physical movement such as jumping among children with DS could be improved.

The determination of motor coordination with the kinematics analysis shall improvise the lower limb muscular strength proficiency and therefore the poor postural control and uncoordinated movement among children with DS. However, there are limited studies available in demonstrating the horizontal jump with related key variables among children with DS. Most of previous studies and locally as concerned were conducted on horizontal jump general protocol of standing broad jump (SBJ) test (Abdullah, Hassan, Pilus, Fauzee, & Omar, 2018), lower limb kinetic muscular, skill-related proficiency (Nadzalan, Mohamad, Lee, & Chinnasee, 2018), and motion analysis of horizontal jump (Baharuddin, Hashim, & Salim, 2009). Thus, there are limited information on the specific jumping pattern and muscular strength properties of horizontal jump. It is fundamental to analyse the motor development component of locomotive horizontal jumping skill and its muscular strength proficiency in children with DS. Therefore, this study was aimed to determine the differences between the rudimentary, functional, and mature horizontal pattern of the jumping performance on the studied kinematic parameters so that the underlying process of the motor learning progression among the impaired motor development of children with DS could be characterized and useful for future motor skills performance improvement.

Methodology

Participants

Twenty-three boys with DS were involved in this study; aged between 4 to 12 years old from the various institutions of DS in the Klang Valley. The recruited children with DS had acknowledged their involvement in the study with prior active consent from

parents or guardians together with study information sheet. Then, they were further screened with Physical Activity Readiness Questionnaire for Children (PAR-Q) (Limerick University Department of Physical Education & Sport Science, n.d). The study had been approved by the ethical committee of Universiti Teknologi MARA [600-IRMI (5/1/6)].

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Procedures

The jumping performance was set as SBJ test protocol (Chow et al., 2014). The protocols included the requirement of participant to stand with feet approximately shoulder-width apart and toes behind a take-off line before jumping. The participants must land with both feet and maintains balance till completion of the action. The jumping performance is allowed with counter- movement of arm and proper placement of feet on ground upon landing. The performance score was evaluated is the horizontal distance (in centimetres) jumped from the take-off line to the part of landing foot nearest to the take-off line. The jumping performance is carried by the participants out on a mat. The horizontal jump distance was determined by a measuring tape by the experimenter.

The jumping performance was recorded with 2 digital videos cameras recording at 50 frame per second. The cameras were placed at frontal area and left sagittal area of the video recording. The frontal camera was placed 230 cm from the start, take-off line or starting place and lateral camera was located 197 cm of the optical axis perpendicular to the centre of the start. Eight retroreflective markers were placed on key anatomical points of left side of body: shoulder, hip, knee and ankle-joint centres and 5th metatarsal joint. The studied data point of jumping phases is the take-off, jump peak height of the highest peak point of centre gravity during flight phase, and point of landing phase as part of the study protocol of (Fernandez-Santos, Gonzalez-Montesinos, Ruiz, Jiménez-Pavón, & Castro-Piñero, 2018; Horita, Kitamura, & Kohno, 1991; Hraski et al., 2015).

The horizontal jumping pattern of SBJ test was measured with study instrument Motor Skills Inventory (MSI) locomotors skill adapted from “California State Polytechnic University, Motor Development Clinic (Wang & Ju, 2002; Werder & Bruininks, 1988). The participants were further classified as rudimentary, functional and mature level accordingly to the movement bodily segments, and limbs.

Data Analysis

One-way ANOVA was performed to determine the horizontal jumping pattern difference between the groups. Meanwhile MANOVA was conducted to compare ROM of lower limb joint during three jumping phases among groups. All statistical analysis in this study was analysed through Statistical Package for Social Sciences (SPSS) (Version 21.0; SPSS, Chicago, IL, USA) with alpha value was set at $p < 0.05$.

Results

Jumping Performance Score

Figure 1 shows the performance score of jumping among the participants. In addition, Results revealed that 91.3% of participants were categorized as ‘poor’ meanwhile the remaining in reasonable category in jumping performance distances. Based on the motor skills inventory analysis, five participants were classified as ‘rudimentary’, nine participants were ‘functional’ and the other nine were in the ‘mature’ level of jumping movement. A significance ($p < 0.05$) difference between rudimentary group ($M =$

22.9±7.09) and mature group ($M = 88.89 \pm 40.34$) was noted with the effect size of $\eta^2_p = .34$.

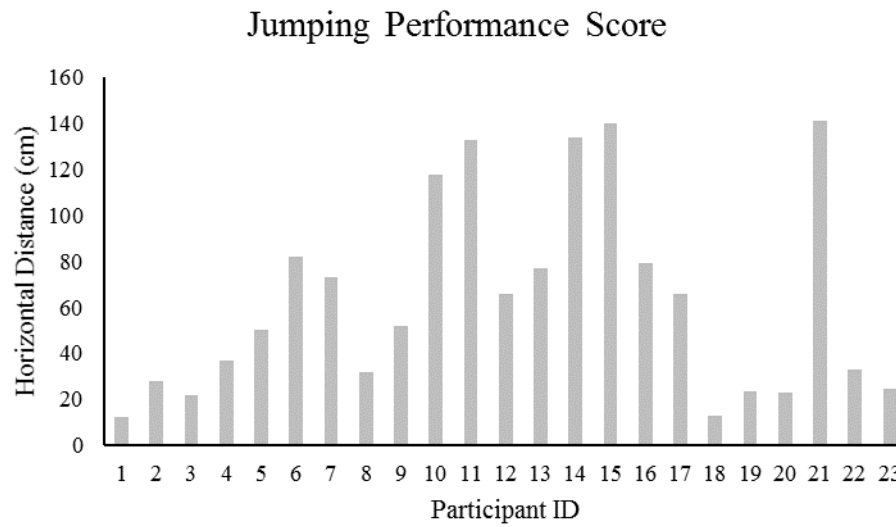


Figure 1 Jumping Performance Score of All Participants

Kinematic analysis of jumping performance

Table 1 showed the overall jumping kinematics among the participants. Further analysis of MANOVA revealed there was no significant difference between the horizontal pattern of jumping performance (Rudimentary, functional and mature groups) on the combined variables $F(2,23) = 1.37, p = .23$; Wilks' Lambda = .24, $\eta^2_p = .51$. The comparison of kinematics analysis of jumping performance between groups is shown in the Table 2. There was no significant difference between the horizontal patterns of jumping performance groups on the combined variables $F(2,23) = 1.37, p = .23$, Wilks' Lambda = .24, $\eta^2_p = .51$. Using Bonferroni in determining separate variables of lower limb joint ROM during the jumping phases, analysis found that the jumping performance had a significant effect on the hip angle ROM of take-off $F(2,23) = 3.50, p = .05, \eta^2_p = .26$ and the rudimentary group had significant difference hip angle ROM ($p = .05$) from the mature group.

Table 1 Jumping Kinematics

		M	SD
Joint ROM of Take-off (°)	Hip	158.30	16.60
	Kn	150.91	11.21
	Ankle	133.17	19.23
Joint ROM of Jump peak high (°)	Hip	152.43	20.53
	Kn	143.43	23.82
	Ankle	134.00	16.43
	Hip	127.87	25.81

Joint ROM of Landin g (°)	Kn ee An kle	150.83 123.17	20.07 16.12
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Table 2 Kinematics Range of Motion of Lower Limb Joints between Groups

Group	Take-off			Jump High Peak			Landing		
	Hip	Knee	Ankle	Hip	Knee	Ankle	Hip	Knee	Ankle
R	143.2±	152.4	141.4	137.4	157.2	145.8	134.0	161.4	132.8
U	20.5*	±13.2	±15.4	±22.3	±11.6	±6.9	±21.0	±9.2	±10.1
F	160.0±	152.6	135.4	156.6	145.1	134.1	128.0	149.3	118.9
U	13.2	±10.9	±15.2	±14.1	±21.3	±18.1	±26.6	±26.6	±17.8
M	165.0±	148.4	126.3	156.7	134.1	127.3	124.3	146.4	122.1
A	13.2*	±11.3	±23.8	±23.1	±28.6	±15.9	±29.4	±16.2	±16.3

Footnote: ROM; Range of motion, RU; Rudimentary, FU; Functional, MA; Mature

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Discussions

The jumping performance among children with DS in this study shared a majority poor prevalence and it was in line with previous study (Lejčarova, 2008; Mello, Nagorny, Haiachi, Gaya, & Gaya, 2016; Werder & Bruininks, 1988). This poor prevalence score of 91.3% are comparable to the jumping performance of normal population (Mello et al., 2016). It was reported that the 40% poor performance prevalence of the jumping performance with the total participants 8,820 typically developing children and adolescent aged 7-17 years old. Present study demonstrated a significant difference between the developmental jumping movements of rudimentary, functional and mature on its performance score. This finding correlated with the developmental progression of motor learning models. The poor conditioning of horizontal jumping movement among children with DS were because of they do initiate and complete movements more slowly and with greater variability than their peers without disabilities of a similar chronological age (Meegan, Maraj, Weeks, & Chua, 2006).

The insignificant difference of horizontal jumping pattern on the kinematic analysis was agreed by previous study (Zimmerman, 1956). The qualitative proficiency of jumping performance between skilled and non-skilled 22 apparently healthy novice and intermediate adults were measured with kinematic key variables of lower limb joint ROM (hip, knee and ankle), and body segmental analysis during the take-off preparation, upward and forward projection, and descent phases. The analysis of developmental jumping movement of among 128 typically developing elementary school boys aged 6-11 years old and 11 apparently healthy male adults (29.2±5.8 years) had found that, the motion of horizontal jump almost mature in the 3rd grade and there was no significant difference between the 6th grade boys and the adults in kinematic key variables of shoulder, maximum shoulder extension angle joint ROM during the back-swing of upper limb, hip and knee joint ROM during bending-down of lower limb (Chen, Ishii, Wang, & Watanabe, 2010). Previous study (Hraski et al., 2015) on the relationship between anthropometrical variable of body segments and kinematic variables of body geometry and bodily joint ROM during 4 stages of jumping (preparation, take-off, flight, and landing phase phases) had found that, there was no significance difference of hip angle and knee angle in all jumping phases except for the negative correlation in hip angle in the lowest point on the centre of mass with lower leg circumference parameter. However, the significant finding of our study on the hip ROM during take-off had been agreed by previous studies. During the jumping movement, the selection of the take-off angle of the

lower trunk flexion on hip angle besides lower knee angle promotes the jumping performance (Fernandez-Santos et al., 2018; Mackala, Stodółka, Siemiński, & Čoh, 2013) analysis on the developmental jumping movement with the age-factor determinant among typically developing children with key variable of take-off angle (Fernandez-Santos et al., 2018) had found that it was significantly correlated in the movement evaluation of horizontal distance ($r = .276$; $p < .01$). Otherwise, the current study finding of hip-knee plots may not give strong impression the significant hip angle of take-off phase across the groups.

Conclusion

This study found that the horizontal jumping performance among Down syndrome children were still in the 'poor' stage. It is recommended that this fundamental movement skills of jumping should be incorporated in the motor development program either conditioning or rehabilitative among children with DS. Future investigations of children with DS motor development shall extends the biomechanical role parameter with more kinematic key variables, and more targeted focus research area. At least research area, study literature and population with corresponding ranging age.

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References

- Abdullah, N. M., Hassan, A., Pilus, M. N., Fauzee, A., & Omar, M. S. (2018). Comparison of sports-specific test protocol and procedures to identify talent in goalball between students with blind and visual impairment. In Yacob N., Mohd Noor N., Mohd Yunus N., Lob Yussof R., Zakaria S. (eds). *Proceedings of Regional Conference on Science Technology and Social Science (RCSTSS 2016)*. Springer, Singapore.
- Baharuddin, M. Y., Hashim, A., & Salim, M. S. M. (2009). *Motion analysis for different type of jumping*. Paper presented at the International Conference on Applications and Design in Mechanical Engineering (ICADME 2009). Penang, Malaysia.
- Capio, C. M., & Rotor, E. R. (2010). Fundamental movement skills among Filipino children with Down syndrome. *Journal of Exercise Science & Fitness, 8*, 17-24. doi:10.1016/S1728-869X(10)60003-2.
- Castro-Piñero, J., Ortega, F. B., Artero, E. G., Girela-Rejón, M. J., Mora, J., Sjöström, M., & Ruiz, J. R. (2010). Assessing muscular strength in youth: Usefulness of standing long jump as a general index of muscular fitness. *Journal of Strength and Conditioning Research, 24*, 1810-1817. doi:10.1519/JSC.0b013e3181ddb03d.
- Chen, Z., Ishii, Y., Wang, Y., & Watanabe, K. (2010). Developmental movement of standing long jump in elementary school children by kinematics analysis. *The Journal of Strength & Conditioning Research, 24*.

- Chow, J. Y., Koh, M., Davids, K., Button, C., & Rein, R. (2014). Effects of different instructional constraints on task performance and emergence of coordination in children. *European Journal of Sport Science, 14*, 224-232. doi:10.1080/17461391.2013.780097.
- Fernandez-Santos, J. R., Gonzalez-Montesinos, J. L., Ruiz, J. R., Jiménez-Pavón, D., & Castro-Piñero, J. (2018). Kinematic analysis of the standing long jump in children 6- to 12-years-old. *Measurement in Physical Education and Exercise Science, 22*, 70-78. doi:10.1080/1091367X.2017.1383913
- Fernandez-Santos, J. R., Ruiz, J. R., Cohen, D. D., Gonzalez-Montesinos, J. L., & Castro-Piñero, J. (2015). Reliability and validity of tests to assess lower-body muscular power in children. *Journal of Strength and Conditioning Research, 29*, 2277-2285. doi:10.1519/JSC.0000000000000864.
- Gallahue, D. L., Ozmun, J. C., & Goodway, J. (2006). *Understanding Motor Development: Infants, children, Adolescents, Adults*. Boston: McGraw-Hill.
- Gupta, S., Rao, B. K., & Sd, K. (2011). Effect of strength and balance training in children with Down's syndrome: A randomized controlled trial. *Clinical Rehabilitation, 25*, 425-432. doi:10.1177/0269215510382929.
- Hardy, L. L., Merom, D., Thomas, M., & Peralta, L. (2018). 30-year changes in Australian children's standing broad jump: 1985–2015. *Journal of Science and Medicine in Sport, 21*, 1057-1061. doi:10.1016/j.jsams.2018.04.005.

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- Horita, T., Kitamura, K., & Kohno, N. (1991). Body configuration and joint moment analysis during standing long jump in 6-yr-old children and adult males. *Medicine & Science in Sports & Exercise, 23*, 1068 - 1077.
- Hraski, M., Hraski, Ž., Mraković, S., & Horvat, V. (2015). Relation between anthropometric characteristics and kinematic parameters which influence standing long jump efficiency in boys and adolescents *Collegium Antropologicum, 39*, 47-55.
- Lejčarova, A. (2008). Level of selected fitness abilities of pupils at practical elementary schools in relation to the aetiology of their intelectual disability. *Acta Universitatis Palackianae Olomucensis. Gymnica, 38*, 45-54.
- Limerick University Department of Physical Education and Sport Sciences (n.d.). *Physical Activity Readiness Questionnaire (PAR-Q) for Children*. Limerick, Ireland. Retrieved September 21, 2017, from <https://www.ul.ie/pess/sites/all/files/PAR-Q%20Children.pdf>
- Mackala, K., Stodółka, J., Siemienski, A., & Čoh, M. (2013). Biomechanical analysis of standing long jump from varying starting positions. *Journal of Strength and Conditioning Research, 27*, 2674-2684. doi:10.1519/JSC.0b013e31825fce65.
- Malak, R., Kostiukow, A., Krawczyk-Wasielewska, A., Mojs, E., & Samborski, W. (2015). Delays in motor development in children with Down syndrome. *Medical Science Monitor : International Medical Journal of Experimental and Clinical Research, 21*, 1904-1910. doi:10.12659/MSM.893377.
- Meegan, S., Maraj, B. K., Weeks, D., & Chua, R. (2006). Gross motor skill acquisition in adolescents with Down syndrome. *Down's syndrome, Research and Practice : Journal of the Sarah Duffen Centre, University of Portsmouth, 9*, 75-80. doi:10.3104/reports.298.

- Mello, J. B., Nagorny, G. A. K., Haiachi, M. D. C., Gaya, A. R., & Gaya, A. C. A. (2016). Projeto Esporte Brasil: physical fitness profile related to sport performance of children and adolescents. *Revista Brasileira de Cineantropometria & Desempenho Humano*, 18, 658-666.
- Nadzalan, A. M., Mohamad, N. I., Lee, J. L. F., & Chinnasee, C. (2018). Relationship between muscle architecture and badminton-specific physical abilities. *Human Movement*, 19(1), 44-50.
- Uyanik, M., Bumin, G., & Kayihan, H. (2003). Comparison of different therapy approaches in children with Down syndrome. *Pediatrics International*, 45(1), 68-73. doi:10.1046/j.1442-200X.2003.01670.x
- Wang, W. Y., & Ju, Y. H. (2002). Promoting balance and jumping skills in children with Down syndrome. *Perceptual and Motor Skills*, 94, 443-448. doi:10.2466/pms.2002.94.2.443.
- Werder, J. K., & Bruininks, R. H. (1988). Assessment, instructional planning and evaluation. In J. K. Werder (Ed.), *Manual of Body Skills* (pp. 84-85). Circle Pines, MN: American Guidance Service.
- Zimmerman, H. M. (1956). Characteristic likenesses and differences between skilled and non-skilled performance of standing broad jump. *Research Quarterly. American Association for Health, Physical Education and Recreation*, 27(3), 352-362. doi:10.1080/10671188.1956.10762011.