

Original Article

STANDING LONG JUMP THEOREM: AN ACCIDENTAL DISCOVERY

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ABSTRACT

Introduction: Assessment of the jumping ability and prescription of jump tasks are integrated in the field of fitness training and physiotherapy rehabilitation. Different kinds of researches on jump analysis have been pursued to gain in-depth knowledge about the kinetics and kinematics of jump biomechanics, in particular, the standing long jump. Standing long jumps can be tested or performed in various ways with alterations in direction of jump (forward, sideward and backward) and leg participation (single leg, double leg). The objective of this article is to share the reports of three types of standing long jump tests conducted for fitness evaluation of clientele; Single Leg Forward Jump (SLFJ), Double Leg Side Jump (DLSJ) and Double Leg Forward Jump (DLFJ), and discuss the accidentally observed trigonometric relationships between these jumps.

Methodology: The data of three types of standing long jump were collected from 10 subjects (males = 7, females = 3) who have been exercising at least 2 - 3 times per week since last six months and they also belonged to different countries like India, Australia, Spain and Israel. All the subjects were allowed to jump with shoes on and all the jumps were done on wooden flooring with a height scale (measuring 0 to 205 cm) kept horizontal to mark the point of take-off and landing. A minimum of three chances were given for each jump and strong verbal encouragement was given to extract the best jumps from the subjects because the best jumps were taken for statistical analyses. After gathering the jump performance data, efforts were made to establish possible unexplored links between these three types of standing long jumps.

Results: A surprising trigonometric relationship between SLFJ, DLSJ and DLFJ was an unexpected finding and accordingly, a formula was devised on the basis of Pythagorean theorem; $DLFJ = \sqrt{(\text{mean DLSJ}^2 + \text{mean SLFJ}^2)}$. Pearson correlation coefficient test was done to understand the degree of relationship between this formula-projected DLFJ and actual DLFJ displayed by the subjects, through which it was found that $r = 0.9987$.

Conclusion: The theorem for standing long jump introduced by this study using an inexpensive technique has been shown highly positively correlating with actual double leg standing long jumps. This theorem can be stated as 'double leg forward standing long jump is equal to or almost equal to the square root of the sum of the squares of standing side jumps (mean of right and left side jumps) and single leg forward standing long jump (mean of right and left single leg forward jumps)'. This study will continue to explore the deeper interconnections of different types of single leg and double leg jumps to contribute further advanced insights to the field of biomechanics and exercise.

KEY WORD: Theorem for standing long jump, Standing long jump, Side jump.

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INTRODUCTION

Assessment of the jumping ability and prescription of jump tasks are integrated in the field of

fitness training and advanced physiotherapy rehabilitation. Different kinds of researches on jump have been pursued to gain in-depth knowl-

edge about the kinetics and kinematics of jump biomechanics, in particular, the standing long jump (double leg forward jump). Standing long jump is a good predictor of sprinting and long jump performance [1]. The standing long jump has become a regularly used assessment among strength and sport coaches to evaluate motor ability and athletic potential [2].

Sophisticated instruments and statistical procedures were used to validate the role of the most critical determinant of superior jump performances. Blake M Ashby et al noted that the subjects jumped 21.2% further on an average with arm movement ($2.09 \pm 0.03\text{m}$) than without ($1.72 \pm 0.03\text{m}$) [3]. Wen-Lan Wu et al found no significant correlations between jump scores and anthropometry data, who also reported that the greater muscle mass or longer leg did not correlated well with the superior jumping performance [4]. Harry John R et al found no acute differences in displacement were observed between barefoot, minimal shoes and cross-trainer shoes during vertical and horizontal jumps but reported that some differences in muscle activation and timing appear to be present and thus, training effects between footwear conditions should be examined [5]. StodóBka J et al investigated on six muscles (m. gastrocnemius, m. gluteus maximus, m. rectus femoris, m. tibialis anterior, m. biceps femoris, and m. vastus medialis) using EMG activation by varying the start positions and noticed that they were almost the same during all phases [6]. Yu Okubo et al observed the highest abdominal muscle activation levels during the push-off phase [7]. William Westphal et al reported that as the distance of the external focus increases (directing attention towards the result of the movement) participants' jump distances would also increase and it appears to be far more effective to provide explicit instructions that promote an external focus of attention [8]. To achieve the best possible performance a jumper must execute a coordinated pattern of countermovement, forward rotation of the whole body, and a double-arm swing as the jumper aims to project his body for maximum horizontal distance beyond a take-off line [9]. Compared with vertical countermovement jump, standing long jump requires more

coordination of movements, timing and technique, since both the takeoff angle and the position of the limbs during takeoff and landing may change the horizontal distance jumped [10]. All safe and productive closed kinetic chain motions occurs as a result of skilled application of forces on the ground, using the requisite strength of the lower limb muscles to derive appropriate ground reaction forces [11].

Standing long jumps can be tested or performed in various ways with alterations in direction of jump (forward, sideward & backward) and leg participation (single leg, double leg). The objective of this article is to share the reports of three types of standing long jump tests conducted for fitness evaluation of clientele; Single Leg Forward Jump (SLFJ), Double Leg Side Jump (DLSJ) and Double Leg Forward Jump (DLFJ).

METHODOLOGY

About ten subjects (males = 7, females = 3) in the age group of 30-45 years, who have been exercising 2 - 3 days per week since six months were assessed for all the three jumps SLFJ (right and left foot), DLSJ (towards right and left sides) and DLFJ, with their exercise shoes on (Photograph 1 - 11). All the jumps were done on wooden flooring with the height scale (0 to 205 cm) kept horizontal to mark the point of take-off and landing. The additional jump distances beyond 205 cm were measured by inch tape. The subjects were instructed to jump from the take off line to maximum long distance possible. The jump distance was measured (i) from the take off line (toe line) to the point of heel placement at landing in SLFJ (ii) from the take off line (toe line) to the point of placement of heels at landing in DLFJ and (iii) from the take off line (lateral border of the lead foot) to the point of placement of lateral border of rear foot in DLSJ. A minimum of three chances were given for each jump and strong verbal encouragement was given to extract the best jumps from the subjects because the best jumps were taken for statistical analyses. Efforts were made to establish any possible mathematical links between these three types of standing long jumps using the jump performance data.

Photograph 1: Shows the top most portion of the height scale that was kept on the floor horizontally to measure the jump performances.



Photograph 2: Shows the starting position for DLFJ at take-off line.



Photograph 3: Shows the finishing position for DLFJ.



Photograph 4: Shows the starting position for DLSJ (L) in which the jump takes place towards left with left foot as the lead foot.



Photograph 5: Shows the finishing position for DLSJ (L).



Photograph 6: Shows the starting position for DLSJ (R) in which the jump takes place towards right with the right foot as the lead foot.



Photograph 7: Shows the finishing position for DLSJ(R)



Photograph 8: Shows the starting position for SLFJ (R) in which the jump takes place forwardly with only right foot on ground.



Photograph 9: Shows the finishing position for SLFJ (R).



Photograph 10: Shows the starting position for SLFJ (L) in which the jump takes place forwardly with only left foot on ground.



Photograph 11: Shows the finishing position for SLFJ (L).



RESULTS AND TABLES

Table - 1 shows the jump score data obtained in centimeters and in order to inform that the samples were not homogenous; the body mass index (BMI) of the subjects has also been included. Interestingly, this study has unearthed a hidden mathematical relationship between these three jumps, in which DLFJ was consistently found obeying Pythagorean theorem (Fig. 1)

Fig. 1: Trigonometric relationship between DLSJ, SLFJ and DLFJ.

$$\text{Formula: DLFJ} = \sqrt{(\text{mean DLSJ}^2 + \text{mean SLFJ}^2)}$$

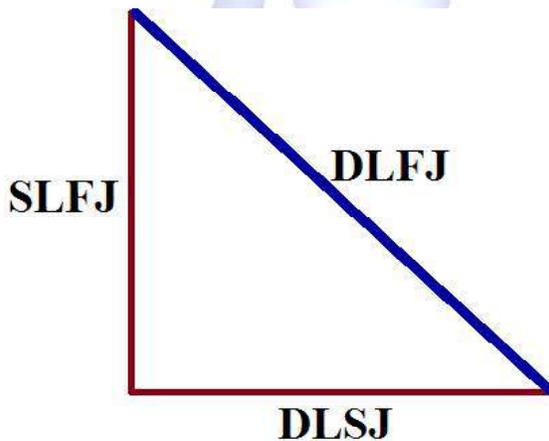


Table - 2 shows the formula-projected DLFJ and actual DLFJ displayed by the subjects. Pearson correlation coefficient tests for all these jumps were performed using the online calculator found in <http://www.socscistatistics.com/tests/pearson/Default2.aspx>, which revealed high positive correlations as shown in Table - 3.

Table 1: Shows the jump performance data of ten subjects along with their BMI. The last three data in the table belongs to female subjects.

Subject's BMI	SLFJ (R)	SLFJ (L)	DLSJ (R)	DLSJ (L)	DLFJ
22	150	150	150	150	213
40.26	124	124	117	118	173*
24.8	115	106	106	108	156
24.67	147	148	138	138	202*
32.8	131	133	148	149	200*
22.6	154	168	135	136	213*
33.1	118	89	121	120	160
19.84	114	102	106	106	150
21.25	133	109	101	101	159*
20.22	140	130	120	120	180*

Table 2: Shows the mean SLFJ, mean DLSJ, formula-projected DLFJ and actual DLFJ. The last three data in the table belongs to female subjects.

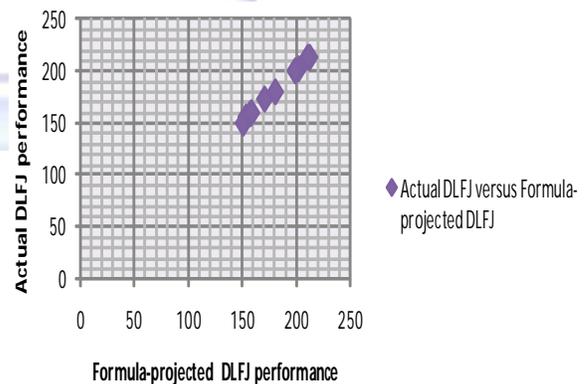
Subject's BMI	SLFJ (R)	SLFJ (L)	Mean SLFJ	DLSJ (R)	DLSJ (L)	Mean DLSJ	Formula projected DLFJ	Actual DLFJ
22	150	150	150	150	150	150	212.1320344	213*
40.26	124	124	124	117	118	117.5	170.82813	173*
24.8	115	106	110.5	106	108	107	153.8156364	156
24.67	147	148	147.5	138	138	138	201.9907176	202*
32.8	131	133	132	148	149	148.5	198.6863106	200*
22.6	154	168	161	135	136	135.5	210.4311051	213*
33.1	118	89	103.5	121	120	120.5	158.8474111	160
19.84	114	102	108	106	106	106	151.3274595	150
21.25	133	109	121	101	101	101	157.6134512	159*
20.22	140	130	135	120	120	120	180.6239187	180*

* Jump performances equal to or more than Personal Height Length (PHL)

Table 3: Jumps Taken for Pearson's Correlation Coefficient Test.

JUMPS TAKEN FOR PEARSON'S CORRELATION COEFFICIENT TEST	CORRELATION COEFFICIENT
Formula-projected DLFJ and actual DLFJ	r = 0.9987
DLSJ (R) and DLSJ (L)	r = 0.9989
SLFJ (R) and SLFJ (L)	r = 0.9097

Graph 1: High positive correlation between actual DLFJ and formula-projected DLFJ.

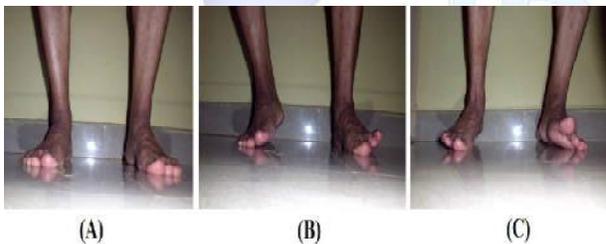


DISCUSSION

The role of calf muscles in producing strong closed kinetic chain (CKC) plantar flexion of ankle to press the ground with the forefoot for jump performances in all desired directions is well known. But the kinetics of side jumps and possible contributions of evertors and invertors of foot seems not thoroughly researched so far. During double leg side jump to the right, the inversion of right foot and the eversion of left foot (both may be occurring at the same time in CKC) may combine with principal CKC plantar

flexion of ankles. During double leg side jump to the left, the inversion of left foot and the eversion of right foot (both may be occurring at the same time in CKC) may combine with principal closed kinetic chain plantar flexion of ankles. (Photograph 12).

Photograph 12: Shows the possible mechanics of foot during side jump (A) Foot at rest (B) Closed kinetic chain inversion of right foot and eversion of left foot to produce side jump to the right (C) Closed kinetic chain inversion of left foot and eversion of right foot to produce side jump to the left. The principal role of calf muscles to produce closed kinetic chain plantar flexion of ankles during these jumps is inevitable. In closed kinetic chain, the eversion can create pressure on the ground from the medial border of forefoot and inversion can create pressure on the ground from the lateral border of forefoot, so that the legs can be moved medially and laterally, respectively.



This study originally began with the curiosity to examine if the DLFJ is equal to the sum of SLFJ (R) and SLFJ (L) but soon got revealed that the DLFJ can be around 60-75% of the sum of single leg forward jump of right and left lower extremities. The scores of side jumps to the right and left also was found very symmetrical for all the subjects. But surprising mathematic relationship between the side jumps, single leg forward jumps and double leg forward jumps (Figure-1) was an unexpected finding, which also should be subjected for further investigations by researchers who have advanced technological resources. About seven subjects in this study with an average or above-average over all physical efficiency were able to perform a double leg standing long jump with a distance which is either equal to or greater than their personal height length (PHL).

Byron Jones (Weight = 90 kg, Height = 1.85 m) set a world record for broad-jump by leaping 3.73m in 2015 [12]. It should be noted here that

Byron's jump distance is twice his PHL. On the basis of this observation of human abilities to perform standing long jump equaling their personal height length and world class performances, a rating system can be formulated and experimented (Table 4).

Table 4: A hypothetical rating system based on jumping ability of humans in relation to their Personal Height Length (PHL).

STANDING LONG JUMP DISTANCE	RATING
Equal to 150% of PHL or more than 150% of PHL	World class athlete
More than 125% of PHL up to less than 150% PHL	Competitive athlete
Equal to PHL up to 125% of PHL	Average athlete
Less than personal height length up to 75% of PHL	Developing athlete
Less than 75% of PHL	Non-athlete

The jump performance data were obtained from subjects who were regularly exercising for at least 2 or 3 days per week since 6 months and jump exercises were also a little part of their exercise regimen, hence the credibility of this new theorem for jump activity can be tested for athletes and non-athletes of various age groups also, with safety precautions. There may be many factors affecting the positive relationship between formula-projected DLFJ and actual DLFJ, for example, musculoskeletal pathology of any joint of a lower extremity or much untrained status of individuals.

CONCLUSION

The standing long jump theorem introduced by this study has been shown highly positively correlating with actual double leg standing long jumps of the exercisers but the biomechanical reasons for how this theorem works yet to be explored. This theorem can be stated as 'double leg forward standing long jump is equal to or almost equal to the square root of the sum of the squares of standing side jump (mean of right and left side jumps) and single leg forward standing long jump (mean of right and left single leg forward jumps)'. The accuracy of the jump score projections of this theorem must be tested further with the help of advanced technologies. In fact, whenever required, Physiotherapists and Fitness professionals can also first measure the SLFJ and DLSJ of their clientele and then

compute the DLFJ using the formula suggested in this study to authenticate the extent of accuracy of the formula-projected jump score in predicting actual double leg standing long jump scores. The theorem also indicates the need of explosive strength of invertors and evertors also because side jump ability is connected with double leg standing long jump and, side jumps may be caused by the additional but significant role of CKC inversion and eversion of foot. It was also consistently noticed in this study and various other routine fitness evaluations that individuals with an average over all physical efficiency are able to perform a double leg standing long jump with a distance which is either equal to or greater than their personal height length but not up to the level of world class athletes who have demonstrated standing long jumps up to 1.75 or 2 times more than their personal height length. The non-athletes and athletes can be trained and guided to enhance their jump performances on the basis of hypothetical standing long jump rating system and the theorem for standing long jump discussed earlier in detail. This study will continue to explore the deeper interconnections of different types and directions of single leg and double leg jumps to contribute further newer insights to the field of biomechanics and exercise.

Conflicts of interest: None

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