CORRELATION BETWEEN JUMP HEIGHT AND BIOMECHANICAL VARIABLES IN CHILEAN ATHLETES OF TEAM SPORTS

Alejandro Bustamante-Garrido[1-2-5-8], Esteban Aedo-Muñoz[3-7-8], Paulina Fuenzalida[4], Hugo Cerda-Kohler[6-5-7], Christopher Moya-Jofré[8], Mauricio Araya-Ibacache[8], Diego García de la Pastora[4], Magdalena Torres[4]

Escuela de Ciencias del Deporte y la Actividad Física, Facultad de Salud, Universidad Santo Tomás, Chile[1]
Navarrabiomed, Complejo Hospitalario de Navarra, Universidad Pública de Navarra, Pamplona, 31008, Spain[2]
Escuela de Ciencias de la Actividad Física, el Deporte y la Salud, Universidad de Santiago de Chile, Santiago, Chile[3]
Especialidad Médica en Medicina del Deporte y la Actividad Física, Facultad de Medicina y Ciencias de la Salud, Universidad Mayor, Chile[4]
Metropolitan University of Educational Sciences (UMCE), Faculty of Arts and Physical Education, Department of Physical Education, Sports and Recreation, Chile[5]
Unidad de Fisiología del Ejercicio, Centro de Innovación, Clínica MEDS, Santiago, Chile[6]
Laboratory of Psychophysiology and Performance in Sports and Combats, Postgraduate Program in Physical Education, School of Physical Education and Sport, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil[7]
Biomechanics Department, Chilean High Performance Center, Santiago, Chile[8]

In elite team sports technical skills and explosiveness are essential to get the optimum performance, being the vertical jump one of the most important motor skills in competition, usually assessed by countermovement jump (CMJ). The main aim of our study is to determine the correlation between jump height and kinetic and kinematic variables using force platforms, and secondly to describe CMJ values of elite Chilean team sports athletes. The results obtained in our study showed a positive correlation between jump height and concentric mean power, concentric peak velocity, concentric peak power and total concentric impulse. These results are fundamental for an optimal analysis of athletes jumping tests, based on data from the specific study population and the use of those variables that are most related to their performance.

KEYWORD: **KINEMATIC, KINETIC, VERTICAL JUMP, COUNTERMOVEMENT JUMP, EXPLOSIVENESS, PERFORMANCE.**

INTRODUCCION: For the optimal participation of athletes on field, monitoring parameters of motor aptitude and technical skills makes possible to identify the strengths and weaknesses of athletes. In elite team sports, specific motor skills such as jumping, sprinting and changes of direction conform a low percentage of the total activity on the field, however, they are decisive in competition (Kabacinski J et al., 2022). In this regard, vertical jump performance has been described as one of the key factors in some sports, and it is described as a movement dependent on the joints and on the explosive power and muscular performance of the lower extremities *(*Sperlich et al., 2016; Shalfawi et al., 2011). Jump assessment is a simple test from which relevant information can be obtained, specifically on the effectiveness of training programs and interventions carried out with the aim of improving the athlete's performance. It also provides information on the sate of the neuromuscular system and muscular fatigue (Macedo et al., 2022; Miranda-Oliveira et al., 2022). The most common vertical jump tests used in biomechanical evaluations are the squat jump (SJ), drop jump (DJ) and countermovement jump without arms (CMJ). Of these three, the latter is one of the most reliable and applicable to high performance sports, because on contrast with the SJ, the CMJ is characterized by containing the complete concentric and eccentric phase of the movement, which means that there is a transfer of elastic energy through the eccentric-concentric cycle and activation of the muscle spindle, allowing or a greater jump height (Macedo et al., 2022).

It is important to determine which variables are relevant in the different jumping phases. Based on the observations of Miranda-Oliveira et al. *(2022),* athletes with higher levels of elastic-explosive strength have superior eccentric characteristics to improve their concentric impulse, take-off speed and jump height. Little has been described on the predictive value of variables within jumping performance in the CMJ. The authors in this review suggests the analysis of other biomechanical variables, such as the temporal and force characteristics during the eccentric and concentric phases of the jump, such as concentric peak power, concentric impulse, total concentric impulse, concentric mean power, concentric peak force, concentric peak velocity, concentric braking RFD-100ms, duration of the different phases, among others. Regarding the above, the objective of this study was to observe the correlation between jump height and other kinematic and kinetic variables in the CMJ, and secondly describe the different values achieved by gender in high performance team sports in Chile.

METHODS: Chilean elite athletes, 32 men (22.5 ± 2.3 years, body mass 79.6 ± 5.8 kg and height 179 ± 3.1 cm) and 11 women (21.2 ± 1.5.3 years, body mass 61.6 ± 3.1 kg and height 165 ± 5.6 cm) , from 3 different team sports (rugby, handball and field hockey) participated on this correlational study . All of them were previously evaluated in CMJ without arms on two force platforms brand Pasco PS-2142 (PASCO Scientific, Roseville, CA) with a sample rate of 1000 hz. For the analysis, the best jump of the 3 performed was considered. Pearson's correlation between the jump height and kinetics and kinematics variables was used, where thresholds values for standardized correlation were 0.0 to 0.3 (negligible correlation), 0.3 to 0.5 (low correlation), 0.5 to 0.7 (moderate correlation), 0.7 to 0.9 (high correlations) and >0.9 (very high correlation). All statistical significance was set at $p < 0.05$ (Schober et al. 2018).

RESULTS Descriptive values are presented by sex as the mean and its standard deviation, with the 95% confidence intervals in Table 1 and Table 2. Table 3 and Table 4 displays the correlations between jump height and kinematic and kinetic variables respectively, considering a significant value of <0.05. The obtained results indicate that among the kinetic variables, concentric mean power, peak power and total concentric impulse have statistically significant moderate to high correlations. In regard to differences between gender, a statistically significant moderate correlation with concentric impulse, concentric RPD and concentric RDP-100 ms is observed only in women. Among the kinematic variables, only concentric peak velocity showed statistically significant moderate to high correlations.

TABLE 1

KINEMATIC VARIABLES WITHIN JUMPING PERFORMANCE IN THE CMJ

	MALE		FEMALE	
	Mean ± Std	CI 95%	Mean ± Std	CI 95%
Jump Height (Flight Time) [cm]	38,02 ± 6,24	2,20 (40,22 - 35,82)	27,68 ± 4,32	1,73 (29,40 - 25,95)
Concentric Peak Velocity [m/s]	2,64 ± 0,20	0,07 (2,71 - 2,56)	2,37 ± 0,14	0,06 (2,42 - 2,31)
Contraction Time [ms]	749,94 ± 66,64	23,46 (773,40 - 726,48)	739,29 ± 81,61	32,65 (771,94 - 706,64)
Eccentric Duration [ms]	481,68 ± 49,81	17,53 (499,21 - 464,14)	465,58 ± 57,93	23,18 (488,76 - 442,41)
Concentric Duration [ms]	268,26 ± 28,56	10,05 (278,31 - 258,20)	273,71 ± 32,47	12,99 (286,70 - 260,72)

CI 95% = 95% confidence interval; Std: Standard Deviation

TABLE 2

KINETIC VARIABLES WITHIN JUMPING PERFORMANCE IN THE CMJ

	MALE		FEMALE	
	Mean ± Std	CI 95%	Mean ± Std	CI 95%
Concentric Impulse [N*s]	209,24 ± 21,65	7,62 (216,86 - 201,62)	140,02 ± 17,55	7,02 (147,04 - 133,00)
Concentric Mean Power / BM [W/Kg]	27,02 ± 3,51	1,23 (28,25 - 25,78)	22,99 ± 2,64	1,06 (24,05 - 21,94)
Concentric Peak Force / BM [N/Kg]	24,74 ± 2,18	0,77 (25,50 - 23,97)	23,33 ± 1,85	0,74 (24,07 - 22,59)
Concentric RPD / BM [W/s/Kg]	238,28 ± 45,11	15,88 (254,16 - 222,40)	194,74 ± 40,73	16,30 (211,04 - 178,45)
Concentric RPD-50ms / BM [W/s/Kg]	309,98 ± 80,33	28,28 (338,26 - 281,70)	266,07 ± 56,95	22,78 (288,86 - 243,29)
Concentric RPD-100ms / BM [W/s/Kg]	266,30 ± 60,69	21,36 (287,66 - 244,94)	216,02 ± 45,43	18,17 (234,19 - 197,85)
Eccentric Braking RFD-100ms / BM [N/s/Kg]	51,81 ± 23,94	8,43 (60,24 - 43,38)	52,25 ± 28,29	11,32 (63,57 - 40,93)
Concentric Peak Power / BM [W/Kg]	47,99 ± 5,68	2,00 (49,99 - 45,99)	40,73 ± 4,68	1,87 (42,60 - 38,86)
Total Concentric Impulse / BM [N s/Kg]	2,50 ± 0,22	0,08 (2,58 - 2,42)	2,24 ± 0,16	0,06 (2,30 - 2,17)

CI 95% = 95% confidence interval; Std: Standard Deviation

TABLE 3

CORRELATION BETWEEN JUMP HEIGHT AND KINEMATICS VARIABLES

	MALE (r)	P value	FEMALE (r)	P value
Concentric Peak Velocity [m/s]	**0.586**	**0.0005***	**0.722**	**< 0.0001***
Contraction Time [ms]	-0.037	0.843	-0.186	0.384
Eccentric Duration [ms]	0.059	0.753	-0.057	0.768
Concentric Duration [ms]	-0.189	0.308	-0.366	0.079

TABLE 4

CORRELATION BETWEEN JUMP HEIGHT AND KINETICS VARIABLES

	MALE (r)	P value	FEMALE (r)	P value
Concentric Impulse [N*s]	0.274	0.136	**0.415**	**0.0439***
Concentric Mean Power / BM [W/Kg]	**0.598**	**0.0004***	**0.719**	**< 0.0001***
Concentric Peak Force / BM [N/Kg]	0.225	0.224	0.220	0.302
Concentric RPD / BM [W/s/Kg]	0.241	0.191	**0.667**	**0.0004***
Concentric RPD-50ms / BM [W/s/Kg]	0.257	0.162	0.307	0.145
Concentric RPD-100ms / BM [W/s/Kg]	0.181	0.329	**0.521**	**0.0091***
Eccentric Braking RFD-100ms / BM [N/s/Kg]	0.150	0.420	0.335	0.110
Concentric Peak Power / BM [W/Kg]	**0.542**	**0.0016***	**0.786**	**< 0.0001***
Total Concentric Impulse / BM [N s/Kg]	**0.685**	**< 0.0001***	**0.713**	**< 0.0001***

r = Pearson’s correlation
*Significative value ($p < 0.05$)

DISCUSSION: Usually, vertical jump performance is defined by jump height. In the last years, researchers have extended the CMJ analysis using kinematic and kinetic variables to obtain a complete overview of the athlete's explosive qualities. It is observed that there is no consensus yet on which variables can best contribute to improve vertical jump performance (Macedo et al., 2022). Regarding kinetics variables, similar to Dowling statement three decades ago (Dowling & Vamos, 1993) and by Merino-Muñoz et al. (2020), our results do not show a correlation between eccentric RFD and jump height. Our findings show that impulse has a moderate to high correlation with jump height, which is consistent with the results reported by Ferragut et al. (2003) who report that 77% of the jump height is determined by this variable. Peak power and peak velocity also have high correlations with jump height (Gonzalez-Badillo & Marques, 2010; Claudino et al, 2017) same as in our results. Our datas show no correlations between RPD, and temporal variables (except for the peak velocity) with jump height. Various articles (Claudino et al, 2017) have correlated jumping height performance to different variables during the concentric phase (concentric peak power, mean power, peak velocity). If we consider that jump height, and the power generated during the jump, is related to several factors such as body mass, push-off distance, force-velocity profile (Morin et al, 2019), the data presented reaffirm the importance of considering other biomechanical variables for monitoring of training loads and the neuromuscular fatigue (Gathercole et al, 2015).

CONCLUSION: The results of our research contribute to the determination of biomechanical variables related to jump height in athletes of team sports, which is useful for the coaching staff to consider them as methods of monitoring and assessment of the training load. Furthermore, for optimal recommendations and analysis of jumping test results, it is highly recommended to have comparative values for the specific study population. Future studies should be conducted to describe normative reference values by gender in other sports and populations.

REFERENCES:

Claudino, J., Cronin, J., Mezêncio, B., McMaster,T., McGuigan, M., Tricoli, V., Amadio, C., & Serrão, J. (2017). The countermovement jump to monitor neuromuscular status: A meta-analysis. *Journal of Science and Medicine in Sport*, *20*(4), 397–402. https://doi.org/10.1016/j.jsams.2016.08.011

Dowling, J., & Vamos, L. (1993). Identification of Kinetic and Temporal Factors Related to Vertical jump Performance. *Journal of Applied Biomechanics*. 1993;9(2):95–110.

Ferragut, C., Cortadellas, J., & Arteaga, R. (2003). Prediccion de la altura de salto vertical. Importancia del impulso mecánico y de la masa muscular de las extremidades inferiores. *Revista Motricidad*,10:7–22.

Gathercole, R., Sporer, B., Stellingwerff, T., & Sleivert, G. (2015). Alternative countermovement-jump analysis to quantify acute neuromuscular fatigue. *International Journal of Sports Physiology and Performance*, *10*(1), 84–92. https://doi.org/10.1123/ijspp.2013-0413

González-Badillo, J., & Marques, M. (2010). Relationship between kinematic factors and countermovement jump height in trained track and field athletes. *Journal of Strength and Conditioning Research*., 24(10):3443–3447.

Kabacinski, J., Szozda, P., Mackala, K., Murawa, M., Rzepnicka, A., Szewczyk, P., & Dworak, L. (2022). Relationship between Isokinetic Knee Strength and Speed, Agility, and Explosive Power in Elite Soccer Players. Int J Environ Res Public Health, 7;19(2):671. doi: 10.3390/ijerph19020671. PMID: 35055489; PMCID: PMC8775831.

Macedo Alfano Moura, T. B., & Alves, Okazaki, V. (2022). Kinematic and kinetic variable determinants on vertical jump performance: a review. *MOJ sports medicine*, *5*(1),25–33. https://doi.org/10.15406/mojsm.2022.05.00113

Merino-Muñoz, P., Pérez-Contreras, J., Bustamante-Garrido, A., & Esteban Aedo-Muñoz. (2020). Relationship between jump height and rate of braking force development in professional soccer players. *Journal of Physical Education and Sport*, *20*(487), 3614–3621.

Miranda-Oliveira, P., Branco, M., & Fernandes, O. (2022). Accuracy of inertial measurement units when applied to the countermovement jump of track and field athletes. Sensors, 22;22(19):7186. doi: 10.3390/s22197186. PMID: 36236284; PMCID: PMC9571243.

Morin, J. B., Jiménez-Reyes, P., Brughelli, M., & Samozino, P. (2019). When Jump Height is not a Good Indicator of Lower Limb Maximal Power Output: Theoretical Demonstration, Experimental Evidence and Practical Solutions. *Sports Medicine*, *49*(7), 999–1006. https://doi.org/10.1007/s40279-019-01073-1

Schober, P., & Schwarte, L. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesth Analg,* 126(5): 1763-1768. doi:10.1213/ANE.0000000000002864

Shalfawi, S., Sabbah, A,. Kailani, G., Tønnessen, E., & Enoksen, E. (2011). The relationship between running speed and measures of vertical jump in professional basketball players: a field-test approach. J Strength Cond Res, 25(11):3088-92. doi: 10.1519/JSC.0b013e318212db0e. PMID: 21993034.

Sperlich, P., Behringer, M., & Mester, J. (2016). The effects of resistance training interventions on vertical jump performance in basketball players: a meta-analysis. J Sports Med Phys Fitness, 56(7-8):874-83. Epub 2015 Jul 14. PMID: 26173791.