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THE EFFECT OF HAND-HELD LOADS ON THE BIOMECHANICAL PARAMETERS OF THE VERTICAL COUNTERMOVEMENT JUMP IN UNTRAINED INDIVIDUALS

Саввопулос Х., Кайсіду В., Мілонас П., Пануцакопулос В., Хатцітакі В. Вплив вантажень в руках на біомеханічні параметри вертикального стрибку в ротирічному руху у непідготовлених осіб.

Ключові слова: *кінетичні параметри, навантаження, потужність, потік енергії, продуктивність.*

Keywords: *kinetic parameters, load, power, energy flow, performance.*

Introduction. The improvement in jumping height is a major concern of coaches and practitioners in a variety of sports. In the case of vertical jumps, the combined use of a countermovement with a coordinated arm swing results in higher jump heights [4]. Due to the former, additional force and work are produce because of the higher active state of the extensor muscles; the latter provides an energy flow that results in increased mechanical work in the lower limb muscles. Both mechanisms eventually result in greater jump height [4].

In Ancient Greece, hand-held loads were used for jumping and it is believed that jumping performance was improved. Contemporary research has shown that the use of hand-held loads in jumping drills during training seems to provoke further performance adaptations youth soccer players compared to their typical training regimes [5].

Previous research found that the use of the hand-held loads alters the biomechanics of the vertical countermovement jump (CMJ) test [2]. Thus, it is of interest to examine how the biomechanical parameters of the CMJ alter when it is performed with hand-held loads. Thus, the aim of the study was to examine the kinetic and spatiotemporal parameters of the CMJ when an arm swing with hand-held loads is allowed in untrained adults. It was hypothesized that CMJ performance and its related biomechanical parameters will be increased due to the arm swing and the loaded arm swing.

Methods. *Participants.* Eight postgraduate students (n = 8, 1 female; 28.3 ± 7.9 yrs, 1.82 ± 0.09 m, 81.9 ± 12.9 kg) voluntary participated in the study. The inclusion criteria were the absence of a recent musculoskeletal or neurological disease for a period up to three months prior testing, and not to participate in systematic training for more than twice weekly. All participants provided singed consents. The study was conducted according to the Declaration of Helsinki and the Research Ethics Code of the Aristotle University of Thessaloniki.

Experimental Procedure. After a warm-up session comprised of dynamic stretching with progressively increasing range of motion, and six CMJ with increasing intensity from sub-maximum to maximum for familiarization, all participants executed, in a random order, three CMJs without an arm swing (CMJA; arms kept akimbo), three CMJs with a free, unloaded arm swing (CMJF), and three CMJs with a free arm swing holding a 2.5-kg weight in each arm (CMJW; 5 kg total load). The command was to «jump as fast and as high as possible», without further instructions concerning the knee flexion during the jump. The intra-test interval was 60 s, while the inter-test rest was 3 min. All CMJs were performed on an AMTI OR6-5-1 force-plate (AMTI, Newton, MA). The sampling frequency for the recording of the vertical ground reaction forces (vGRF) was set to 500 Hz.

Data analysis. Before extraction, the data were smoothed with a 2nd-order digital low pass Butterworth recursive filter, with the cut-off frequency set to 20 Hz. The jump height was calculated from the body center of mass (COM) vertical take-off velocity, which in turn was calculated as the first-time integral of the net vGRF using the trapezoid rule. All examined parameters were extracted based on the vGRF-time series, the participants' mass and classical equations of motion. Only the best attempt (criterion: jump height) was selected for further analysis.

Statistical analysis. Data are presented as mean ± standard deviation. Normality of distribution and the equality of variance were assessed using the Kolmogorov-Smirnov test ($p > 0.05$) and the Levene's test ($p > 0.05$), respectively. A one-way ANOVA with Bonferroni adjustment and Tukey's HSD *post hoc* test was used to examine the effects of the arm swing on the kinetic parameters of the CMJ. Significant differences were followed up with pairwise comparisons. Effect sizes were checked using the eta-squared statistic (η^2). Small, medium, and large effect size were determined by extracted values of above 0.01, 0.06, and 0.14, respectively. All statistical tests were conducted using the IBM SPSS Statistics v.27 software (International Business Machines Corp., Armonk, NY, USA). The level of significance was set at $a = 0.05$.

Results. Representational time-curves of the vGRF and power output are presented in Figure 1. The patterns were different among the examined CMJ tests.

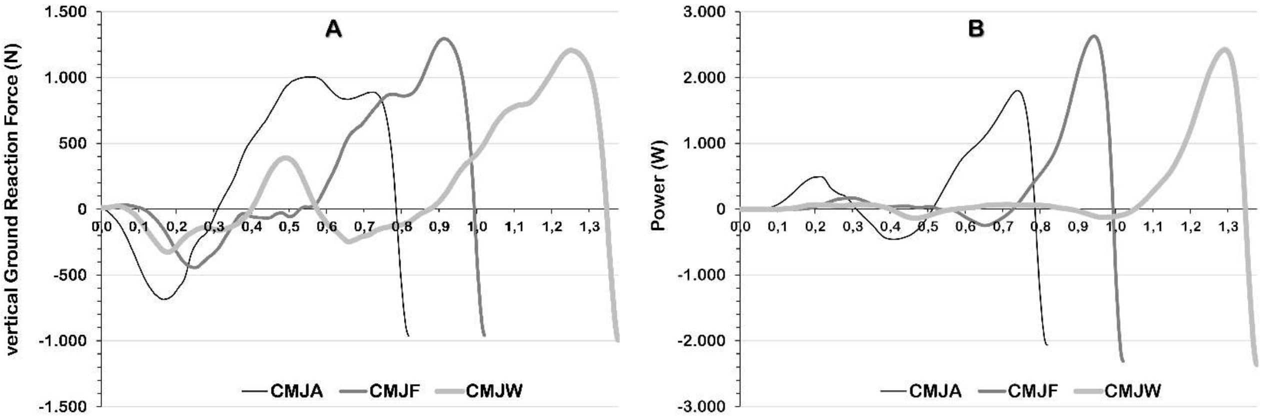

Fig. 1. Representational time-curves of the vertical ground reaction force (A) and power (B) for the examined countermovement jump tests *(CMJA: no arm swing; CMJF: free arm swing; CMJW: loaded arm swing with 5-kg hand-held weights)*

Results revealed that no significant ($p > 0.05$) inter-test difference existed for the CMJ kinetic and spatial parameters (Table 1). The jump height in the arm swing CMJs was not significantly ($p > 0.05$) higher than the CMJA. Regarding the temporal parameters, the arm swing CMJs had significantly ($p < 0.05$) larger duration of the entire push-off and braking phases, as well as larger time to achieve peak vGRF and peak power (large effect size). However, no significant ($p > 0.05$) differences were observed between CMJF and CMJW.

Table 1

Mean ± standard deviation of the biomechanical parameters among the examined countermovement tests (n = 8)

Parameters	CMJA	CMJF	CMJW	F	p	η^2
jump height (cm)	32.0 ± 8.2	38.2 ± 8.6	37.0 ± 8.2	1.261	0.304	0.107
peak net vGRF (kN)	1.1 ± 0.1	1.2 ± 0.3	1.2 ± 0.2	0.327	0.725	0.030
relative force (N/Kg)	2.4 ± 0.2	2.4 ± 0.2	2.3 ± 0.2	0.530	0.597	0.048
peak RFD (kN/s)	11.8 ± 4.7	9.9 ± 3.5	8.3 ± 2.4	1.880	0.177	0.152
peak power (kW)	2.0 ± 0.5	2.1 ± 0.7	2.6 ± 0.7	3.267	0.058	0.237
downward vertical COM displacement (cm)	33.5 ± 6.4	31.3 ± 3.3	32.6 ± 5.7	0.366	0.698	0.034
upward vertical COM displacement (cm)	46.1 ± 6.3	48.1 ± 4.9	50.4 ± 5.5	1.166	0.331	0.100
total push-off time (ms)	834 ± 106	1234 ± 234*	1435 ± 357*	11.528	<0.001	0.523
breaking phase (% Total Time)	66.0 ± 3.8	74.0 ± 3.8*	75.1 ± 5.7*	10.596	<0.001	0.502
time to achieve peak vGRF (% Total Time)	68.5 ± 7.0	87.8 ± 8.0*	90.1 ± 5.0*	24.479	<0.001	0.700
time to achieve peak power output (% Total Time)	91.2 ± 0.8	94.1 ± 1.1*	94.5 ± 1.1*	25.218	<0.001	0.706

NOTE:
p < .05 vs. CMJA;
CMJA: arms akimbo;
CMJF: unloaded arm swing;
CMJW: loaded arm swing with hand-held weights;
vGRF: vertical ground reaction force;
RFD: rate of force development;
COM: center of mass.

Discussion. The findings the present study revealed that no differences between the CMJs with free and loaded arm swing. Nevertheless, both jumping modalities had significantly larger values in the examined temporal parameters compared to the CMJ without an arm swing.

The findings of the present study are in reasonable agreement with previous research [2]. In specific, although it was found that the arm swing augmentation of the jump height was approximately 19.6 % that indicates good coordination ability during the execution of the CMJ [1], the addition of the hand-held load did not result in further improvement concering the jump height. This confirms past findings suggesting that the performance of the CMJ with an arm swing is not linearly improved with the increase of the mass of the hand-held loads [2-3].

The lack of further jump height improvement due to the hand-held load can be explained from the absence of significant improvements in power. The temporal rather than the kinetic parameters were different between the CMJs with the arm swing compared to the CMJ without the arm swing. The examination of the time-curves of the CMJ kinetic parameters confirms that coordination is impaired due to the added load.

It should be noted that there were some limitations in this study. At first, the participants comprised a small sample size. The second limitation is that the hand-held load was not individualized as a percentage of body mass. Instead, a fixed 5-kg of additional hand-held load was applied regardless of the participant's body mass. Thus, it is possible that the participants could not optimize their coordination to perform the CMJW as they might were not able to deal with the applied load.

In conclusion, the use of hand-held loads ~ 6 % of body mass will not result in the enhancement of CMJ performance in untrained adults. Future studies should research the optimum individualized hand-held load that could be applied on not-systematically trained adults to optimize the augmentation of their jumping performance utilizing both the countermovement and the arm swing.

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