Comparison of Vertical Ground Reaction Forces At Impact While Vertical Jumping Using Soft and Pretensed Landing Mechanics

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INTRODUCTION

This study compared the effects of soft and pretensed landing mechanics on ground reaction forces (GRF) at impact while performing repetitive maximal vertical jumps.

METHODOLOGY

Ten active and healthy college-age males performed three jumping trials of a maximal counter-movement jump using a pretensed (stiff) or a soft landing followed by another maximal vertical jump while landing on a force plate. The force plate's analog to digital convertor and range amplifier was electronically zeroed and calibrated prior to each subject's data collection. The vertical ground reaction forces (Fz GRF) of two jumps and landings were collected over an eight second period at a sampling frequency of 100 Hz with an Ariel APAS system using a Kistler piezoelectric force plate. Each jumping movement was delineated into three phases: propulsive (PROP), flight (FLT), impact/landing (IMPACT). The vertical GRF (Fz) at impact for the first jump, propulsive GRF during the second jump for three trials were analyzed for the soft and pre-landing techniques using a 2x3 ANOVA with repeated measures on all factors. Additionally the flight times and heights for both jumps, time to peak landing impact, contact time during the jumping propulsion and the slope of the GRF loading during the first landing phase were calculated and statistically analyzed.

RESULTS and DISCUSSION

The subjects' mean body mass was 85.0 $\pm$ 14.2 kg, mean height was 179.3 $\pm$ 7.3 cm and the mean age was 23.2 $\pm$ 3.6 years. Table 1 provides a summary of the vertical GRF (Fz) during propulsion one and impact, propulsion two, flight and impact times, slopes of the Fz GRF at impact and vertical jump height.

The mean propulsive GRF exerted during the initial counter-movement jump was 2345 Nt (301% BWT) for the soft landing trials and 2478.9 Nt(316%BWT) for the pretensed landing trials. These significant differences represented in Fig. 1 were due to the subjects altering their jumping technique in anticipation for the pretensed landing.

The analyses found no significant differences between the flight times and heights achieved during the initial counter-movement jump. These findings would indicate that the bodys' impact velocities were similar between the type of landing prior to impact and therefore would not be an influencing factor in the vertical GRF observed at impact [1].

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TABLE I

Fz GRF and GRF Slope at Propulsion and impact, Flight Time, and Jump Height During Soft and Pretensed Landing Mechanics

	Soft landing (M$\pm$SD)	Pretensed	F Prob Signif Land, Trial, LxT
JUMP #1			
Propulsive Time (Sec)	.829 $\pm$ .133	.771 $\pm$ .108	NS,NS,NS,
Propulsive Fz GRF (Nt)	2345.0 $\pm$ 602.0	2478.9 $\pm$ 639.4	Land p=.013
Propulsive Fz GRF (%BWT)	301.1 $\pm$ 44.3	316.2 $\pm$ 41.9	Land p=.013
Flight Time	.568 $\pm$ .052	.576 $\pm$ .604	NS,NS,NS
Ht (Cm)	39.8 $\pm$ 7.2	40.7 $\pm$ 8.1	NS,NS,NS
Impact Fz GRF (Nt)	2691.4 $\pm$ 420.4	3087.3 $\pm$ 781.1	Land p=.049
Impact Fz GRF	348.3 $\pm$ 67.3	399.9 $\pm$ 71.6	Land p=.025
Impact Time (Sec)	.089 $\pm$ .026	.099 $\pm$ .028	NS,NS,NS
Impact Fz GRF Slope	31155 $\pm$ 9505.3	35652.6 $\pm$ 14302.0	NS,NS,NS
JUMP #2			
Propulsive Time (Sec)	.588 $\pm$ .148	.381 $\pm$ .088	Land p=.000
Propulsive Fz GRF (Nt)	2217.6 $\pm$ 465.5	2845.0 $\pm$ 810.1	Land p=.002
Propulsive Fz GRF (%BWT)	286.1 $\pm$ 29.0	367.2 $\pm$ 76.6	Land p=.003
Flight Time	.572 $\pm$ .049	.576 $\pm$ .057	NS,NS,NS
Ht (Cm)	40.4 $\pm$ 6.9	41.0 $\pm$ 7.8	NS,NS,NS

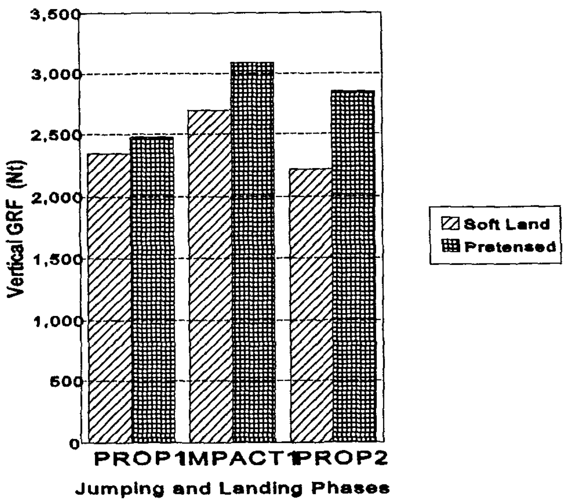

Fig.1 Vertical GRF during propulsive and impact phases while jumping using soft and pretensed landings.

The statistical analyses found differences between the soft and pretensed landings for the impact GRFs when expressed as an absolute impact force (p=.049) and as a percentage of body weight (BWT) (p=.025). When a soft landing technique was employed to absorb a 39.8 cm vertical impact, a mean absolute GRF of 2691 Nt and a body weight normalized GRF of 348% BWT was exerted on the floor at landing. A typical GRF tracing for a soft landing is shown in Fig.2.

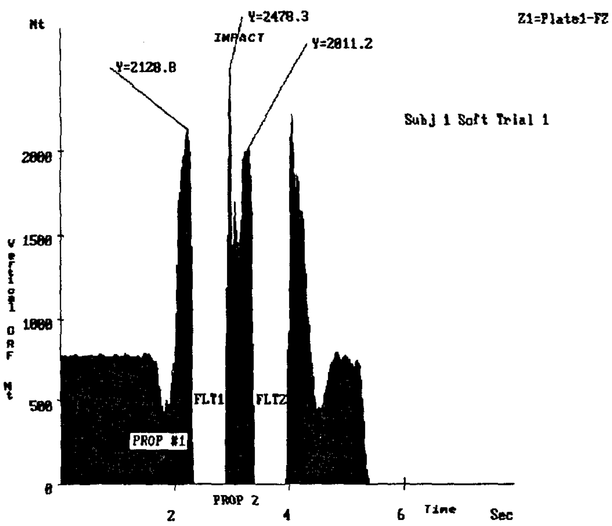

Fig. 2 Typical vertical GRF tracing during repetitive vertical jumping with soft landing.

While a pretensed landing from a 40.7 cm drop yielded impact GRFs of 2083 Nt (400% BWT) and a typical GRF force tracing for pretensed landing is shown in Fig. 3.

The pretensing of the leg musculature in preparation for a repetitive jump resulted in a stiffening of the elastic component of the leg which magnified the impact forces by 115%. The magnitudes of the impact GRFs become problematic for the prevention of landing injuries when considering elite athletes having vertical jumps of 75-100 cm instead of the 40 cm vertical heights achieved by average subjects [1,2].

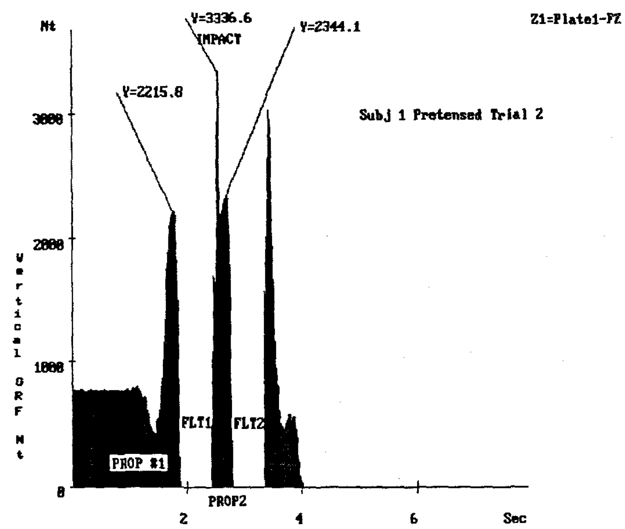

Fig. 3 Typical vertical GRF tracing during repetitive vertical jumping with pretensed landing.

Similarly, elevated GRFs at impact for a discrete stiff landing or pretensed landing were reported by Schot and Dufek for comparable drop heights [3]. The degree of extension of the lower extremity or the pretensing of the leg musculature in preparation for landing, are techniques that may increase the knee joint stiffness prior to contact. The fully extended leg landing technique used sometimes in gymnastics landings rely on the articular cartilage muscular elasticity and bone structure to absorb the abrupt compressive impact forces [4]. This rapid impact loading of the bone will result in higher energy storage by the bone [5] but the consequences of repetitive impacts at a high rate of loading may eventually lead to repetitive bone fatigue fractures [6]. The alternative landing technique involves pretensing the leg musculature in order to increase the elastic stiffness of the musculature acting across the knee joint, which will attenuate and damp the rapid loading experienced at impact during landing. Increased leg stiffness has been reported by DeVita and Skelly [7] to produce in greater impact forces and a faster eccentric phase for the pretensed landing.

No statistical differences were found to exist between the soft and pretensed landings for the impact time. The mean impact times were $.089 \pm .026$ sec and $.099 \pm .028$ sec for the soft and pretensed landings, respectively. This finding was contrary to the results reported by DeVita and Skelly [7] and probably was due to the subjects' inexperience with depth/drop jump and plyometric training.

No differences were found between the soft and pretensed landing for the slope of impact GRF curve. The mean slope for the soft landing trials was 31155±9505 Nt/Sec and the mean slope for the pretensed trials was 35652.6±14303 Nt/Sec. The lack of statistical significance was due to the large variability in the impact slopes and the time of impact, which again was probably due to the subjects' plyometric inexperience or a need for a larger number of trials.

During the second jump following the pretensed landing, a shorter takeoff time (p=.000) was accomplished due to the storage of the elastic energy stored in the leg musculature stiffened by the pretensed landing. The mean propulsive times for the repetitive (second) jump were .381±.088 sec and .588±.148 sec during the pretensed and soft landings, respectively.

In addition, to a faster jump for the pretensed landing, the pretensed technique resulted in a larger propulsive GRF. The mean propulsive GRF for the pretensed trials was 2845 Nt(367%BWT) and the mean propulsive GRF for the soft landing was 2217 Nt (286%BWT)

Analysis of the flight times and height showed no significant differences between the two techniques of landing. Therefore, landing technique did not influence the flight characteristics of the repetitive jump but the pretensed landing improved the take off time and propulsive force. Other studies in the literature [8] have reported an improvement in vertical height jumped when depth/drop jumping techniques are employed.

CONCLUSIONS

This study found that the GRFs at impact after a maximal vertical jump were greater for jumps using a pretensed landing than a soft landing in preparation for a maximal repetitive jump. The time of impact and slope of impact loading exhibited during pretensed and soft landings were found to be similar due to a large variability in the landing technique employed by average jumpers. A faster propulsive phase was found for the second jump using a pretensed landing than a soft landing. Greater GRFs were applied to the floor during the propulsive phase of the repetitive jump as a result of the storage of elastic energy in the muscle for the pretensed landing than the soft landing. Pretensed landings during repetitive jumping increased the impact and propulsive GRFs while reducing the propulsion time without affecting the flight time or vertical height. Therefore, pretensed landings may be desirable for faster repetitive maximal jumps but the increased impact forces may increase the potential for fatigue fractures.

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