OPTIMAL HEIGHTS IN THE DEPTH JUMP FOR REACTIVE ABILITY AND MAXIMAL STRENGTH REFLECT THE FORCE-TIME CHARACTERISTICS OF SPORT'S PROPULSIVE DEMANDS

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INTRODUCTION: The "Shock Method" of plyometric training uses impact-driven, forcible muscle action to provoke the stretch receptors, resulting in elastic energy recoil during the reversal phase of the stretch-shortening cycle (Bosco Viitasalo, Komi and Luhtanen, 1982). Additionally, the greater starting heights of a depth jump stimulate high-end motor cortex involvement when compared to lower heights of the drop jump. Thus, the improvement in motor unit synchronization, recruitment and firing rate (Verkhoshansky, 2012) benefit the kinetic (impulse) and temporal (rate of force development) variables which drive propulsive performance (Kollias, Panoutsakopoulos and Papaiakovou, 2004). Significant increases in the performance of traditional jump exercises and lower-body power tests occurred when compared with traditional methods alone (Kultury et al., 1987; Shepperd, Newton & McGuigan, 2008; Verkhoshansky, 1968).

While it is evident that athletes of varying sport backgrounds exhibit different propulsive parameters (Kollias, Hatzitaki, Papaiakovou, and Giatsis, 2001), no literature exists concerning the tendency for sports of varying backgrounds to exhibit propulsive forces differently in the depth jump. The researcher's primary hypothesis was optimal heights for explosive strength and reactive ability, and maximal strength among high-level Rugby, Hockey, Rowing, Fencing and Swimming vary. The secondary hypothesis was that the force-, time- and performance-based variables measured significantly differ by drop height and by sport. The purpose of the study was to establish optimal heights for explosive strength & reactive ability, and maximal strength in the depth jump.

METHODS: A cross-sectional design was implemented similar to Verkhoshansky, 1968. Depth jumps were performed in 20-cm increments from 40 to 100-cm. Sixty-seconds were provided between each jump attempt for an adequate recovery period. While minimizing the time commitment for participants. Twenty-eight participants volunteered to take part in this investigation. The mean age, height and mass were 20.4(±2.0) years, 169.3 (±43.2) cm, and 82.8 (±27.3) kg, respectively. All participants were high-level athletes, performing on 1st team University and/or national squads. All participants completed participant information and consent forms. Ethical approval was granted by the University of Edinburgh's institutional ethics committee. Ethical guidelines for the assessment of all jumps followed The British Association of Sport and Exercise Sciences (BASES). All jump assessments were made using a Kistler force plate (Type 9281; A G Kistler, Winterhur, Swtzerland).

The data were analyzed using Two-Way Analysis of Variance with one repeated measure. When significance was observed ($p < 0.05$, a Bonferroni post-hoc test was used to determine the difference in height and a Tukey HSD for differences between sports. The main effects of sport, starting height, and the interaction effect between sport and height are provided in Table 1. The independent variables were Sport (between groups factor) and drop height (within groups factor). To determine the degree of difference for between-groups and within-groups statistics, effect size statistics were calculated using Partial Eta Squared (η^2_p). Small, medium and large effects were 0.0099, 0.0588, and 0.1379, respectively (Richardson et. al, 2011).

RESULTS: Results are summarized in Table 1. Optimal height for explosive strength and reactive ability, and maximal height are displayed in Figure 1. The influence of sex must be taken into consideration as all Rugby and Rowing participants were male, compared to an entirely female Fencing group and majority female Hockey and Swimming group. An optimal height of 80-cm was selected for Hockey and Rowing because these values fell within 3-mm (<1%) of the greatest ForceMax recorded at 40-cm. Although the Swimmers' optimal starting height for maximal strength was lower, the ForceMax produced at optimal height was greater than Rowing (1%) and within 1% less than Hockey. Similarly, the ForceMax of Rowing at 40-cm greatly exceeded Rugby (10%), Hockey (16%), Swimming (17%) and Rowing (13%).

Table 1: Results of Statistical Analysis

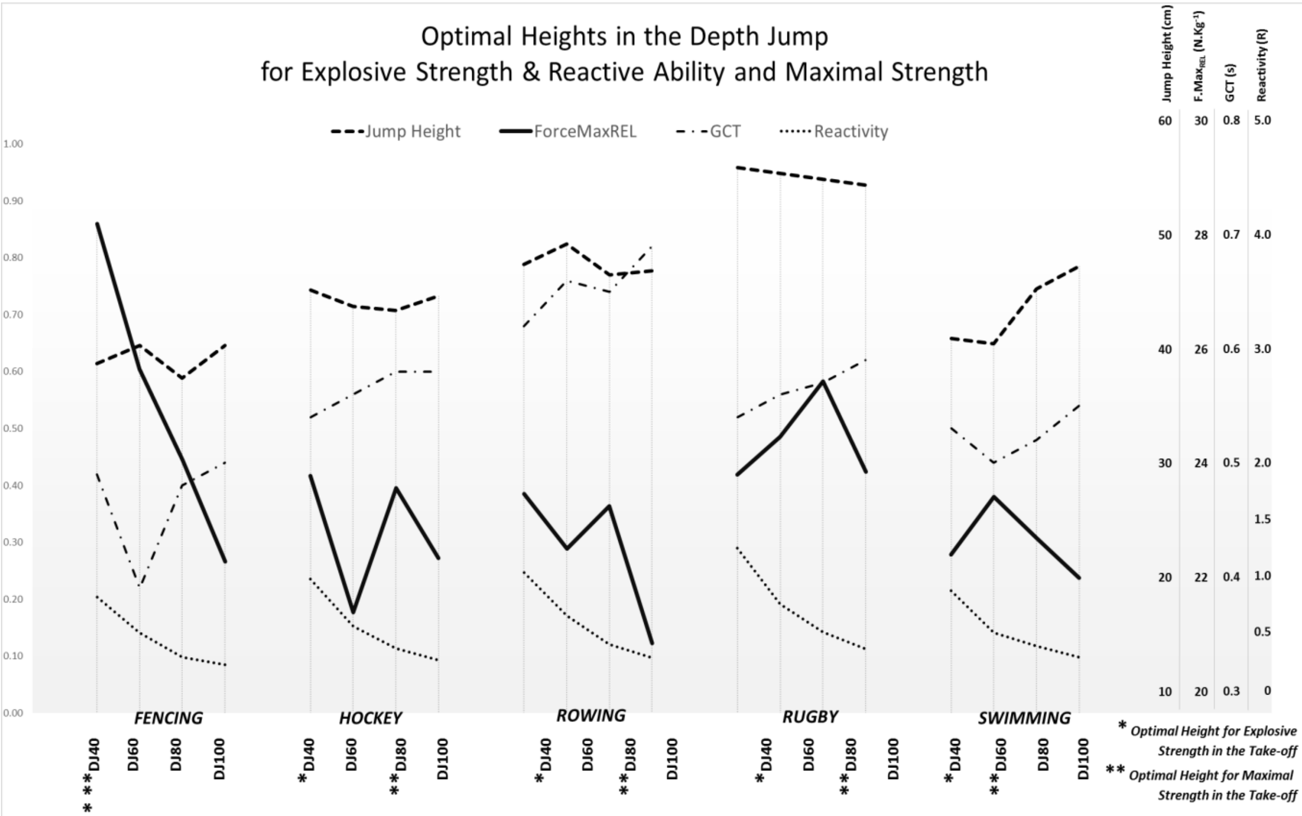
	Main Effect: Height	Main Effect: Sport	Interaction Effect: Height By Sport	Pairwise Comparisons
H_{DJ} (cm)	*p*=0.496 (η^2_p=0.029)	p=0.004 (η^2_p=0.476)*	*p*=0.097 (η^2_p=0.029)**	Rugby x Fencing, p=0.004* Rugby x Hockey, p=0.032* Rugby x Swimming, p=0.035*
$ForceMax_{ABS}$ (N)	*p*=0.036 (η^2_p=0.122)*	*p*=0.088 (η^2_p=0.287)**	*p*=0.459 (η^2_p=0.148)	None
$ForceMax_{REL}$ ($N.Kg^{-1}$)	*p*=0.040 (η^2_p=0.113)*	*p*=0.656 (η^2_p=0.097)	*p*=0.440 (η^2_p=0.150)	None
T_{ECC} (s)	*p*=0.009 (η^2_p=0.178)*	*p*=0.247 (η^2_p=0.202)	*p*=0.023 (η^2_p=0.298)*	None
GCT (s)	*p*=0.036 (η^2_p=0.133)*	*p*=0.167 (η^2_p=0.237)	*p*=0.503 (η^2_p=0.139)	None
Reactivity (R)	*p*<0.001 (η^2_p=0.967)*	*p*=0.002 (η^2_p=0.509)*	P<0.001 (η^2_p=0.998)*	Rugby x Fencing, *p*=0.002* Rugby x Hockey, *p*=0.024* Rugby x Swimming, *p*=0.013*
S_{REL} ($Kg.BM^{-1}$)	N/A	*p*=0.010 (η^2_p=0.429)*	N/A	Rugby x Fencing, *p*=0.015* Rugby x Hockey, *p*=0.020*
EUR_{FM} (N)	*p*=0.025 (η^2_p=0.134)*	*p*<0.001 (η^2_p=0.969)*	*p*=0.392 (η^2_p=0.158)	Fencing x Rowing, *p*=0.081**

* = The mean difference is significant at the 0.05 level; ** = The mean difference approaches significance.

DISCUSSION: The investigation resulted in statistically significant differences in the force-, time- and performance-based variables measured. These findings reflect the subtleties in propulsive forces that characterize the sport's demands and drive depth jump performance. The results of this investigation suggest a relationship between the capacity to produce force and starting height in the depth jump.

PRACTICAL APPLICATION: It is conclusive of this investigation that high level athletes of acceleration-based sports, and non-running-based sports with a greater capacity for force production (speed-strength) should train at optimal training heights of 40- and 80-cm for explosive strength and reactive ability and maximal strength in the take-off, respectfully; while acceleration- and non-ground-based sports that excel in speed-strength should train at optimal heights of 40- and 60-cm, respectively.

Figure 1. Optimal Heights in the Depth Jump



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