COMPARISON OF FIVE DIFFERENT TAKE-OFF THRESHOLDS WHEN ASSESSING COUNTERMOVEMENT VERTICAL JUMP PERFORMANCE

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INTRODUCTION

Athletic testing and monitoring are essential for the strength and condition professional in order to manage an athlete's neuromuscular fatigue that results from the athlete's training program. Vertical jump height is a simple measure that can be used to evaluate neuromuscular readiness for resistance training (13). When performed on a force plate, vertical jump testing can provide additional metrics that can be used to identify important biomechanical factors relating to performance (4,9).

Being able to reliably identify when the jumping motion begins and when take-off occurs are two methodological concerns that influence several metrics used to assess jump performance. While several studies have evaluated different methods for identifying movement initiation (1,11,12), there has been no direct comparison in jump performance when using different methods for identifying take-off. Methods for identifying take-off include when the vertical ground reaction force (VGRF) drops below 20 N (5), 10 N (1), 5 N (7), when the VGRF equals 0 N (8), and when the VGRF drops within five standard deviation of the first 300 ms of the flight phase (10).Therefore, the purpose of this investigation was to compare several kinetic and kinematic metrics using several different take-off thresholds.

METHODS

Using a repeated measures design, twenty-one college-aged participants (n = 9 females [21 ± 1 yrs, 165.4 ± 4.8 cm, 68.3 ± 19.5 kg], n = 12 males [23 ± 3 yrs, 179.1 ± 5.5 cm, 84.7 ± 10.9 kg]) completed two sessions (familiarization and experimental). All procedures and protocols were approved by the University's Institutional Review Board. During the first (familiarization) session, participants completed the informed consent and health history questionnaire. Following a standardized warm-up, participants performed several practice VJs on a portable force plate (Kistler Type 9260AA6; Kistler Instruments AG, Winterthur, Switzerland). All jumps were performed with the participants' hands on their hips.

For the experimental session, participants completed a five-minute warm-up at a self-selected pace on a motorized treadmill. Following the treadmill warm-up, each participant was taken through a standardized dynamic warm-up over a distance of 14 m by one of the investigators. After the dynamic warm-up was completed, each participant performed two sub-maximal (50% and 75%) effort countermovement VJs on the force plate with 30 seconds of rest between each jump. Following 30 seconds of rest, participants completed five maximal effort countermovement VJs with one-minute of rest between each jump.

Force plate data were sampled at 1000 Hz, collected using BioWare (Version 5.4.8, Kistler Instruments AG), and exported to be analyzed offline using a custom software program written in Python. Dependent variables analyzed were jump height (JH), movement time (MT), reactive strength index modified (RSImod), net impulse (netIMP), and propulsive impulse (prIMP) using each of the following take-off thresholds: when the VGRF initially went below 20 N, 10 N, 5 N, < 1 N, and within five standard deviations of a 300 ms window during the flight phase (5SD).

System weight was determined by taking the mean VGRF over the first second of data collection during quiet stance on the force plate. The beginning of the jumping movement was determined when the VGRF dropped below five standard deviations from system weight. Take-off was determined using the following thresholds: when the VGRF initially went below 50 N, below 20 N, below 10 N, below 1 N, and when the VGRF dropped within 5SD. The beginning of the flight phase was identified as 30 ms after the VGRF went below 10 N and the end of the flight phase was identified as 30 ms prior to VGRF exceeding 10 N. Net force was determined by subtracting the system weight (i.e., jumper's body weight) from the VGRF. NetIMP was determined by integrating the net force and time from movement initiation to take-off. This integration began 30 ms prior to this 5SD threshold (12). JH was determined using the impulse-momentum method. MT was the time elapsed between movement initiation and take-off. RSImod was determined by dividing JH by MT (3). Acceleration-time curve was calculated by dividing the net force by the participant's body mass. Velocity-time curve was calculated from the integral of acceleration and time. The propulsive phase of each jump began at the end of the braking phase and ended with take-off. The end of the braking phase was determined when the velocity was closest to zero (2). PrIMP was determined by the product of the average net force and duration of time for this phase of the jump.

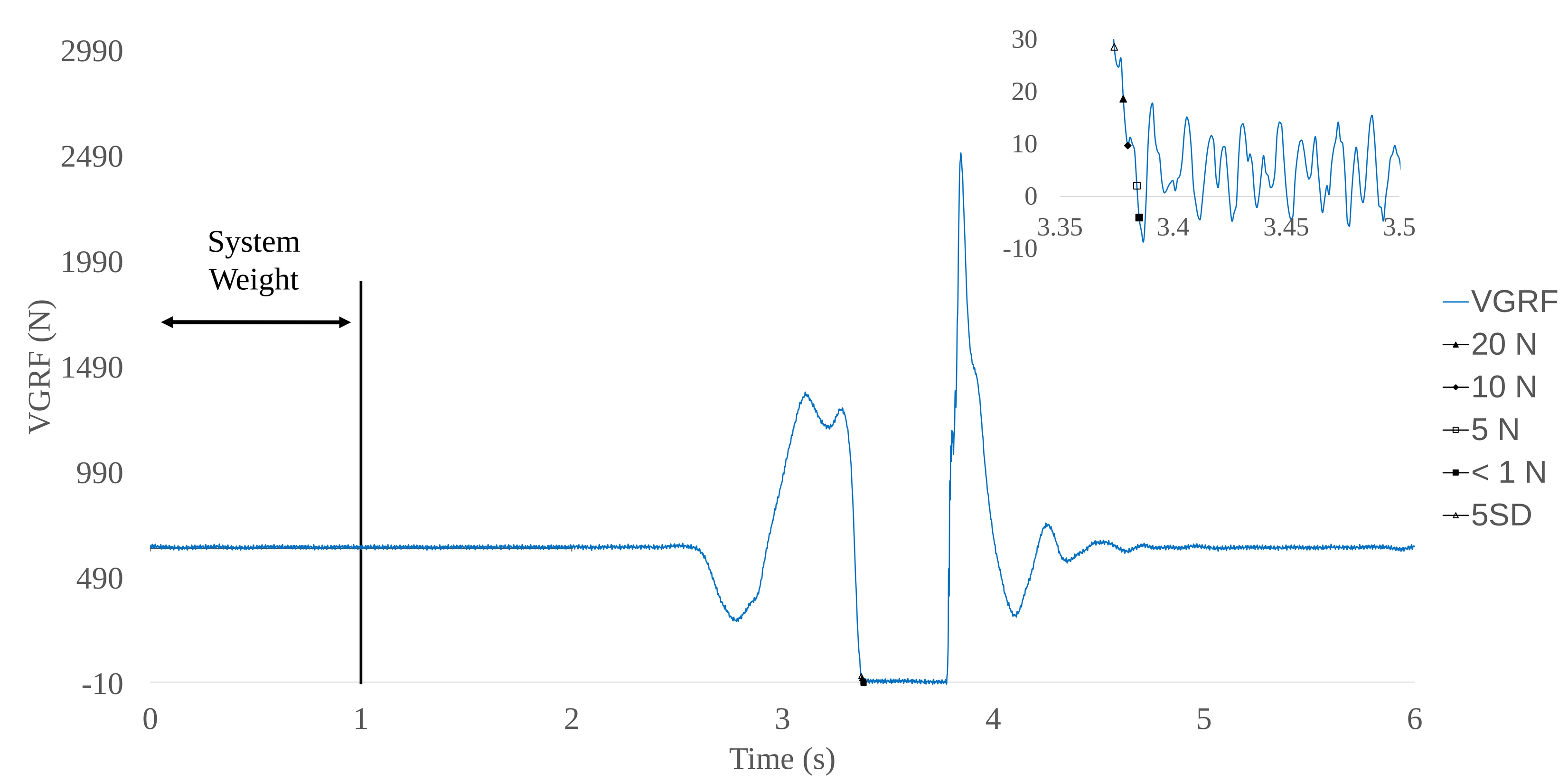
Statistical Analysis

Absolute and relative reliability were determined using coefficient of variation (CV) and intraclass correlation coefficients (ICC), respectively. Separate repeated measures ANOVAs (RMANOVA)were used to assess differences among the thresholds in terms of JH, MT, RSImod, netIMP, and prIMP. Greenhouse-Geisser correction was used when the assumption of sphericity was violated. Pairwise comparisons using Bonferroni correction was used when the RMANOVA demonstrated statistical significance. ICCs and their 95% CI were interpreted using the following scale: < 0.5, poor; between 0.5 and 0.75, moderate; between 0.75 and 0.9, good; > 0.90, excellent reliability (9).Hedge's g was used to determine effect sizes. Effect sizes were calculated by hand using Hedges' g. Magnitude of effect size were interpreted using the following scale: 0..0 to 0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large; 2.0 to 4.0, very large; 4.0+, nearly perfect (6). Alpha level was set to 0.05.

RESULTS

There was a consistent pattern in terms of ranking the take-off thresholds based on time of occurrence. Figure 1 shows a typical force-time graph that identifies each take-off threshold.

Figure 1. Force-time graph of a subject (65.2 kg) showing the system weight assessment period as well as the five take-off thresholds.



The RMANOVA results showed that JH was significantly different across the different take-off thresholds (F = 92.021, p < 0.001). The RMANOVA for MT was also significantly different across all take-off thresholds (F = 10.077, p < 0.001), RSImod was significantly different across the different take-off thresholds (F = 46.778, p < 0.001). NetIMP was also significantly different across the different take-off thresholds netIMP (F = 82.860, p < 0.001). The RMANOVA for prIMP was also significantly different across all take-off thresholds (F = 82.709, p < 0.001). Table 1 shows the results of the pairwise comparisons using the Bonferroni correction for all VJ metrics for each take-off threshold.

Table 1. Means (SD) of VJ metrics for each take-off threshold.

	20N	10N	5N	< 1N	5SD
JH (cm)	29.8 (10.0)[1]	29.2 (10.0)[1]	29.0 (10.1)[1]	28.7 (10.2)[1]	30.0 (10.1)[1]
MT (s)	1.148 (0.230)[2]	1.149 (0.230)	1.151 (0.229)[3]	1.151 (0.229)[3]	1.146 (0.228)[2]
RSImod	0.27 (0.10)	0.26 (0.10)[1]	0.26 (0.10)[1]	0.26 (0.10)[1]	0.27 (0.10)
netIMP (Ns)	186.98 (57.47)[1]	185.29 (57.32)[1]	184.50 (57.54)[1]	183.32 (57.94)[1]	187.82 (161.62)[1]
prIMP (Ns)	187.48 (57.85)[1]	185.78 (57.71)[1]	185.00 (57.93)[1]	183.82 (58.33)[1]	188.31 (57.95)[1]

Means (SD)
[1]significantly different from all other thresholds (p < 0.050, g = 0.01-0.11)
[2]significantly different from < 1N threshold (p = 0.022, g = 0.02-0.15)
[3]significantly different from 5SD (p < 0.01, g = 0.02-0.15)

Table 2. ICC and CV for the different take-off thresholds.

		20 N	10 N	5 N	< 1 N	5SD
JH	ICC [95% CI]	0.975 [0.953, 0.989]	0.972 [0.947, 0.988]	0.972 [0.947, 0.988]	0.965 [0.933, 0.984]	0.977 [0.957, 0.990]
	CV%	4.9	5.1	5.2	6.0	4.7
MT	ICC [95% CI]	0.837 [0.718, 0.924]	0.839 [0.720, 0.924]	0.838 [0.719, 0.924]	0.835 [0.715, 0.922]	0.835 [0.714, 0.922]
	CV%	6.4	6.4	6.4	6.4	6.4
RSImod	ICC [95% CI]	0.916 [0.847, 0.962]	0.920 [0.854, 0.964]	0.919 [0.852, 0.964]	0.911 [0.840, 0.959]	0.915 [0.844, 0.961]
	CV%	8.5	8.5	8.8	9.7	8.5
netIMP	ICC [95% CI]	0.992 [0.984, 0.996]	0.991 [0.982, 0.996]	0.990 [0.981, 0.996]	0.988 [0.976, 0.955]	0.992 [0.985, 0.997]
	CV%	2.4	2.5	2.6	3.0	2.3
prIMP	ICC [95% CI]	0.992 [0.984, 0.996]	0.991 [0.983, 0.996]	0.991 [0.982, 0.996]	0.988 [0.977, 0.955]	0.993 [0.986, 0.997]
	CV%	2.3	2.4	2.5	2.9	2.3

CONCLUSIONS

The purpose of this investigation was to compare five different take-off thresholds when assessing JH, MT, RSImod, netIMP, and prIMP produced during countermovement VJs. All thresholds produced acceptable absolute reliability and good-to-excellent relative reliability as measured by CV and ICC, respectively. In our set-up, the peak force produced during the flight phase was ~17 N. It would seem reasonable to use the 20 N threshold for our force plate and environment, given this amount of noise in the signal. While there were many statistically significant differences among these thresholds, the effect sizes associated with these differences were categorized as trivial. Therefore, these differences may not be practically meaningful.

PRACTICAL APPLICATIONS

These data suggest that any of these take-off thresholds can be used reliably to assess JH, MT, RSImod, netIMP, and prIMP. When deciding upon which method to use, we recommend considering the noise contained within the force signal while selecting the threshold that preserves more of the force-time curve.

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