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A kinetic and kinematic assessment of the band assisted countermovement jump

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Running title; countermovement jump assessment

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Abstract

This study sought to elucidate kinetic and kinematic differences between unloaded and band assisted countermovement jumps (CMJ). In a randomised order, 20 healthy subjects (mass 84.5±18.6 kg) completed 3 repetitions of CMJs across three conditions; unloaded (at body mass), low and moderate band (8.4±1.9 and 13.3±3.3 kg body mass reduction, respectively). For all repetitions, a force platform and linear position transducer were used to record and calculate kinetic and kinematic data during the eccentric, concentric, and landing phases. Body weight was significantly different between the unloaded, low, and moderate band conditions (*P*<0.05). Peak velocity, absolute peak and mean force and movement duration displayed a trend that was mostly related to the condition (i.e. unloaded> low>moderate) (*P*<0.05). The opposing trend (i.e. moderate>low>unloaded) was generally observed for relative peak and mean force, reactive strength index modified and flight time (*P*<0.05). No differences were observed for mean velocity, movement duration and absolute and relative landing forces (*P*>0.05). The use of band assistance during CMJs can alter force, time and velocity variables. Practitioners should be aware of the potential positive and negative effects of band assistance during CMJs.

Key words; variable resistance, force, impulse, power, velocity

INTRODUCTION

Success in team, racket, and ball sports requires athletes to elicit high levels of force, impulse, velocity, and power during sprints, changes of direction and jumping tasks (11,23,32) These ballistic movements require the athlete to apply a force to accelerate their mass as quickly as possible (i.e. high impulse) (37). Importantly, these kinetic and kinematic variables (i.e. force, impulse, velocity, power) are related to sporting tasks and can distinguish between populations (13,26). Given the importance of these variables in the sports context, it is pertinent that practitioners adopt methods to enhance these variables in their athletes.

There are a variety of methods that can be used to improve kinetic and kinematic variables acutely, e.g. nutritional aids (17), variable resistance training (16) and conditioning activities (18,38). However, these effects are short-lasting (<15 minutes), and their effectiveness is contingent on continued use. Practitioners therefore opt for resistance and plyometric training methods to enhance these mechanical variables longitudinally (9,19). Some authors suggest that these can be done on the basis of high force/low velocity, high velocity/low force and mixed-methods training types (7,37), although certain movements (e.g. plyometrics) demonstrate both high forces and velocities.

Though the best method of training is subject to debate (e.g. Cormie & Flanagan, 2008), and likely will continue to be, coaches will often employ a variety of different methods, dependent on the seasonal contexts and periodisation strategies. For example, a common method involves the prescription of band assisted movements (e.g. banded CMJ) to increase the velocity of the exercise (5,39–41), which is known as overspeed training. Indeed, since athletes can be profiled as force or velocity deficient (22,36), the use of ‘overspeed’ type methods has gained popularity. Whilst previous work has shown that band assisted training can improve CMJ height (39), evidence from our work in the applied setting and preliminary data (4) does not support this. Moreover, Sheppard et al. (39), examined only jump height, which fails to account for differences in jump strategy (technique) (15,34). For example, the same jump performance can be achieved by increasing force and decreasing time, or by decreasing force and increasing time (34).

Before further longitudinal intervention studies can be performed, it is important to understand the kinetic and kinematic differences between unloaded and band assisted CMJs. To date no study has provided a kinetic and kinematic assessment of the banded CMJ compared to its unloaded variation. Therefore, the aim of this study is to determine if there are kinetic and kinematic differences between unloaded and band assisted CMJs. Given the lack of comparable reports, we propose the null-hypothesis (i.e. no difference between conditions).

METHODS

Experimental approach to the problem

A repeated-measures design was employed to determine the kinetic and kinematic differences between unloaded and band assisted CMJs. Subjects attended the rehabilitation gym on a single occasion where they performed a standardised warm-up (2 sets of 10 body mass squats, dynamic lower-body stretching (2 sets of 10 front, back and sideways leg swings, walking spiderman lunges and lateral lunges), 1 set of 5 submaximal unloaded CMJs and 1 set of 5 maximal CMJs) and habituation trials to band assisted CMJs. For the habituation trials, participants performed trial repetitions until their flight time values plateaued (3,12). Thereafter, in a randomised order, subjects performed 3 sets of 3 CMJs with either no band (unloaded), a low band (8.4 ± 1.9kg) or moderate (13.3 ± 3.3 kg) band. Subjects were given 15s rest between jumps and 5 minutes between conditions.

Subjects

Twenty healthy males (n = 16) and females (n = 4) (age 24.1±3.8y, mass 84.5±18.6 kg, stature 1.78±0.1 m) were recruited for the study via convenience sampling. All subjects habitually exercised, were asymptomatic of illness and lower-body injury and familiar with unloaded and band assisted CMJs. Subjects completed a health-history questionnaire and informed consent prior to testing. Ethical approval was attained from the host institution’s ethics committee (ETHICS2019-33).

Procedures

To assess the influence of the bands on kinetic and kinematic variables, subjects performed 3 sets of 3 CMJs with no band, a low and moderate band. Subjects set up for all CMJs by standing on the centre of the force platform with their knees and hips fully extended, and feet approximately hip-width apart (33). Subjects stood 15 to 20 cm (~6 to 8 inches) away from the point at where the band attached to the rig to remove the risk of them hitting their heads. Subjects kept their hands placed across their shoulders in a fixed position throughout the jump. The nylon cord of a linear position transducer was held in their right hand and on their left shoulder. Subjects were instructed to lower themselves to a self-selected depth before performing a rapid countermovement before jumping as high as possible (14,15,33). For the assisted conditions, a band (104.4cm [41 inches], Strength Band, Perform Better, UK) was attached to a rig (Free standing, BLK BOX, UK) at either 2.15 (n=12) or 2.44m (n=8) (for those shorter and taller than 1.8m, respectively) above the force platform (see Figure 1 for further details). The band was stretched and placed across the back and underneath the subjects’ armpits (92.8±11.5cm between bar and armpit). The depth of the countermovement was not standardised as the band would likely affect this. Moreover, because we wanted to determine if the band had an effect on landing ground reaction forces, subjects were not given any instructions on their landing technique. Comparable procedures have been previously used elsewhere (41).

[INSERT FIGURE 1 ABOUT HERE]

Data acquisition and analysis

All jumps were performed on a force platform (Force Decks, Vald Performance, Brisbane, Australia) with the nylon strap of the GymAware (placed laterally to the force platform;

GymAware PowerTool, Kinetic Performance Technologies, Canberra, Australia) held in the subjects' right hand, and on the left shoulder. The force platform was used to record force-time data, whilst the GymAware was employed to calculated peak and mean velocity data. The GymAware measures displacement over time and was used to calculate peak and mean velocity and power. The weight calculated during the weighing phase of each condition was inputted into the GymAware. The angle measurement of the GymAware was turned on to account for the GymAware location in related to the subject. The GymAware has been deemed a valid and reliable tool in the assessment CMJ performance (42). The force platform, which samples at 1000 Hz, was zeroed prior to the subjects standing on the platform. During the weighing phase (i.e. silent period), subjects were instructed to stand still to determine body weight. Once subjects were stood still (confirmed via visual flatline on the force-time curve), the subjects were instructed to perform the CMJ. Data were analysed via the Force Decks software (version 2.0.7594). This software defines the initiation of the movement as a 20 N deviation from the initial body weight recording. A series of metrics (i.e. peak and mean force across the movement, peak landing force, movement duration, reactive strength index and flight time) were automatically calculated via the Force Decks software. These metrics can be found in the Force Decks user manual and glossary of terms. The ForceDecks is deemed a reliable tool in the assessment of kinematic and kinetic variables (31). Given the very poor reliability of rate of force development metrics, these were not included in the current study (31). Moreover, variables between phases (i.e. concentric and eccentric) and impulse variables were not included as changes in body weight during the movement (induced by the band) can cause errors in these outcome variables. Note that these procedures have been previously used elsewhere (31). The inter-repetition intraclass correlation coefficient and coefficient of variation (both ±95% confidence intervals) for flight time (the variable we used to habituate participants) in the current study was 0.99 ± 0.16, 0.98 ± 0.21 and 0.99 ± 0.16 and 7.4 ± 1.2, 7.4 ± 1.2 and 8.0 ± 1.3 % for the unloaded, low and moderate band conditions, respectively.

Statistical analysis

Data were checked for normality using Shapiro-Wilk statistics, and these assumptions were repeatedly found to be satisfied (*P* > 0.05). A repeated-measures analysis of variance (ANOVA) was used to determine differences between conditions. If the assumption of sphericity was not met, the Greenhouse-Geisser correction was used. Where necessary a *post hoc* t-test was employed to locate differences in specific pairwise comparisons, with a Tukey LSD correction. Effect sizes (ES; Cohen's *d;* difference between means/pooled standard deviation) were calculated to determine the size of the differences between significant pairwise comparisons. This allows for a more practical and meaningful explanation of the data. Thresholds for the magnitude of the observed change for each variable were qualified as *trivial* (< 0.20), *small* (0.20 to 0.59), *moderate* (0.60 to 1.19), *large* (1.20 to 1.99), or *very large* (>2.00) (6). Pearson's correlations (*r*) (±95% confidence intervals) were used to determine the relationship between the band stretch with selected kinematic and kinetic variables. The strength of the correlations was interpreted using the following criteria: *trivial* (±0.10), *small* (±0.10–0.29), *moderate* (±0.30–0.49), *high* (±0.50–0.69), *very high* (±0.70–0.90), or *practically perfect* (±0.90). Alpha was set at 0.05.

RESULTS

The repeated-measures ANOVA revealed significant differences in body weight between the unloaded, low and moderate band conditions (*F*=318.8, *P*<0.001). *Post hoc* analysis found that body weight was higher in the unloaded (84.5±18.5 kg) than low (77.4±18.1 kg; *t*= 19.7, *P*<0.001, ES=0.39±0.52) and moderate conditions (72.5±17.5 kg; *t*=18.1, *P*<0.001, ES=0.66±0.53) and higher in the moderate than low conditions (*t*=13.6, *P*<0.001, ES=0.28±0.52). Consequently, the moderate band reduced body weight to a greater extent than the low band (8.4±1.9 vs 13.3±3.3 kg, respectively; *t*=13.6, *P*<0.001, ES= 1.82±0.62).

[INSERT FIGURE 2 AND 3 ABOUT HERE]

Table 1 details the repeated measures ANOVA and *post hoc t* test statistics for all variables collected during the CMJs. In summary, peak velocity, absolute peak and mean force displayed a trend that was generally related to the condition i.e. greater values unloaded > low > moderate ($P < 0.05$). The opposing trend (i.e. great values for moderate > low > unloaded) was observed for relative peak and mean force, reactive strength index modified and flight time ($P < 0.05$). Mean velocity, movement duration and absolute and relative peak landing force were not different between conditions ($P > 0.05$).

[INSERT TABLE 1 ABOUT HERE]

The relationship between the stretch of the band during the low and moderate conditions with selected kinetic and kinematic variables was non-significant for all comparisons (Table 2; $P > 0.05$).

[INSERT TABLE 2 ABOUT HERE]

DISCUSSION

To the authors' knowledge, this is the first study to provide a comprehensive kinetic and kinematic comparison between unloaded and band assisted CMJs. Generally, absolute kinetic and kinematic variables were higher in the unloaded condition than in the band assisted conditions. Conversely, relative kinetic values displayed the opposing trend to absolute values. These data suggest that if practitioners want to maximise the magnitude of absolute kinetic and kinematic variables when training with or assessing CMJ performance, the unloaded condition should be prioritised.

Both unloaded and banded jump methods are deemed effective training strategies to improve vertical jumping ability (28,43). In that sense, a better understanding of the kinetic and kinematic differences between unloaded and band assisted CMJs can help practitioners to select the best training strategy for an athlete. The present findings show higher peak and mean force in unloaded condition than the banded conditions, with a comparable movement time. These data could indicate that the participants were producing a greater ‘total’ force in the unloaded condition, by both producing greater force over a similar period of time (34). Given that relative peak and mean force were greater with the bands, it is likely that the greater peak and mean force in the unloaded condition are partially explained by the greater weight. Nonetheless, higher peak and mean force in the unloaded condition compared to the banded conditions are likely owing to greater fast-twitch muscle fibres’ involvement or higher muscle activation (8). It is suggested that that at the onset of movement neural receptors sense the load (weight) and recruit the appropriate number of motor units and rate of firing (2,16). (20)Moreover, the greater ground reaction forces in the unloaded condition compared to the band assisted ones is in line with the maximal dynamic output hypothesis (21,29) This theory indicates the during rapid movement (i.e. jumping) the leg muscles are designed to produce their maximum dynamic output at their out body mass (21,29). This provides reason as to why kinetic variables were maximised during the unloaded condition compared to the band assisted ones.

Assisted jump training can be used to enhance velocity output (i.e. the velocity end of the force-velocity spectrum), because it exposes the athlete to supramaximal velocities beyond what they can typically produce (41). The higher velocity during banded conditions compared to unloaded can be attributed to the bands reducing the individual's body weight (27,41). Though previous studies report higher velocities for assisted jump compared to unloaded jumps (1,10,27), the current study observed the opposite (i.e. greater in unloaded than banded). It is unlikely that differences in body weight reduction via the bands explains the differences between our findings (8.4 ± 1.9 and 13.3 ± 3.3 kg for low and moderate band, respectively). Tran and colleagues (40) suggest that to induce changes in jumping variables, body weight should be reduced by 10 to 30%. In the current study, the selected banded reduced body weight by 10.3 ± 3.3 and 16.1 ± 5.3% (low and moderate bands, respectively), which falls within the suggestion from Tran et al. (40). It is therefore likely that the higher peak and mean force, coupled with similar movement time (indicating a greater impulse), generated in the unloaded condition compared to the banded conditions explains the differences in velocity (34,35,44). That is, the banded conditions reduced peak and mean force, and likely impulse, to the extent that peak velocity is being impaired. Indeed, this is in line with Newton's second law of motion and the impulse-momentum relationship. Moreover, change in velocity is a consequence of the force the athlete is producing over time (e.g. impulse). Therefore, methods which maximise force and impulse in the training environment are paramount. Given that the banded conditions reduced peak and mean force and peak velocity, practically we suggest that they should not be selected over unloaded CMJs when seeking to enhance jump performance or create overspeed.

In the present study, a higher reactive strength index modified was observed in the banded conditions compared to the unloaded condition. Banded CMJs produce greater take-off velocity and due to the constant acceleration of the centre of mass and subsequently a higher jump height (41). This positively influences flight time, one of the constituent variables driving reactive strength index modified, which was substantially higher in banded condition than unloaded. Moreover, the use of bands alters biomechanical patterns through the range of motion so that mechanically weaker positions are supported (24). The higher reactive strength index modified during the banded conditions compared to unloaded could also be explained by enhanced utilization of the stretch-shortening cycle with bands. Indeed, the use of bands results in greater relative eccentric force, promoting higher spindle stimulation and elastic energy storage, and then augmenting relative concentric force (30). A final explanation for the greater reactive strength index modified, and flight time, in the banded conditions could be due to the action of the band reducing the gravitational acceleration from the point of maximal displacement (i.e. top of the jump) to landing. Readers should be aware that half flight time, is used to estimate maximal vertical displacement (i.e. jump height), based on the assumption that flight follows a parabolic relationship. It is possible that the use of bands could skew the flight relationship and cause half flight time to incorrectly estimate jump height. However, this provides a direction for future research to investigate.

From a practical standpoint, the use of bands during CMJs could be used to reduce landing forces. Surprisingly, all conditions produced comparable peak and relative landing forces. Previous work has demonstrated a positive relationship between additional load during CMJs and landing force (25). Our findings contrast this, perhaps owing to subjects jumping with reduced, rather than additional mass. (25)Practically, this suggests that banded jumps will not alter landing force. Given that there may be certain scenarios (e.g. rehabilitation) where landing forces need to be managed, future work is needed to confirm our observations.

A major implication of this work is for practitioners to determine the effect of the band relative to the athlete's ability to express force. For example, these data show that flight time was higher in the banded condition than the unloaded (moderate > low > unloaded). However, this was a result of band assistance (and lower body mass) rather than the athlete's neuromuscular capabilities (i.e. force production) as suggested by the lower peak and mean force and likely impulse (given the similar movement time) in the banded conditions than the unloaded conditions. From a training perspective, it is unlikely that adaptations to jump training will be maximised if the athlete is not producing the necessary forces themselves.

PRACTICAL APPLICATIONS

To the authors' knowledge, this is the first study to provide a comprehensive kinetic and kinematic detail of unloaded and banded CMJs. Absolute kinetic and kinematic variables were higher in the unloaded condition than the banded conditions. Conversely, relative values displayed the opposite to absolute values for the kinetic data. From a practical standpoint, if certain force, velocity and time variables are to be altered during training, then practitioners should be aware of the implications of band assistance during CMJs. Moreover, banded CMJs provide little, if any, benefit when seeking to reduce landing forces.

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Disclosure statement

There are no conflicts of interest.

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Figure 1. Banded countermovement jump setup.

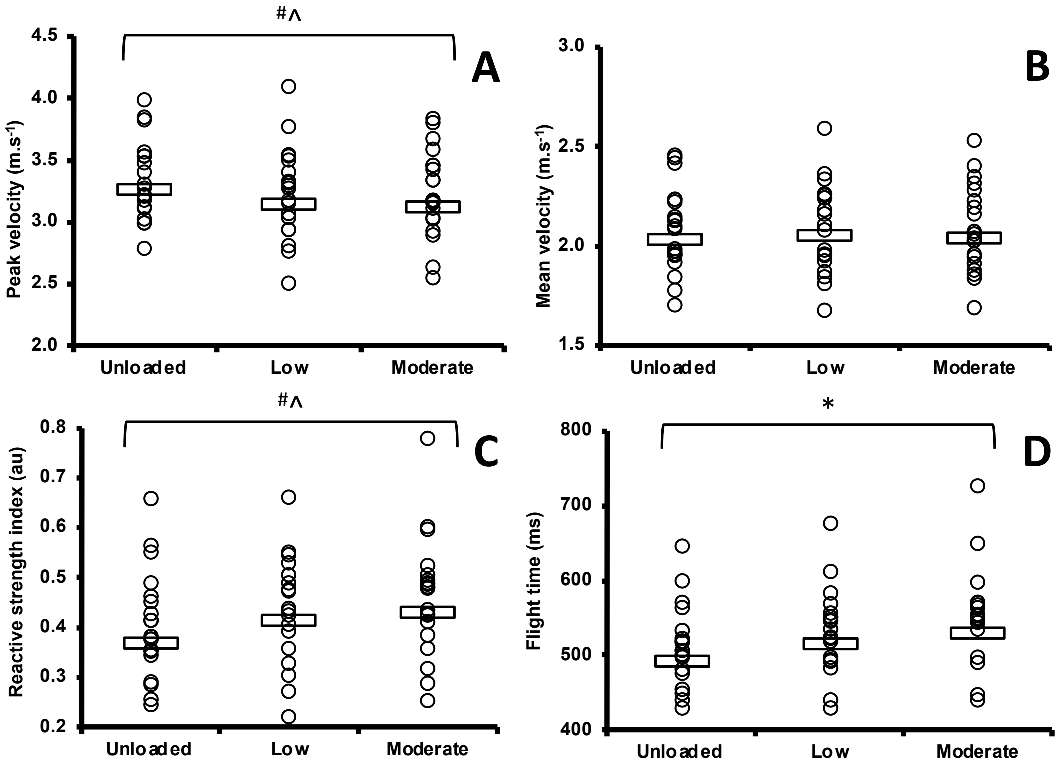

Figure 2. Selected countermovement jump variables. For comparative purposes, grey lines connect the individual values for each participant. The black rectangles denote the average of each condition. *, differences between all conditions (P<0.05). #, differences between unloaded and low band (P<0.05). ^, differences between unloaded and moderate band (P<0.05).

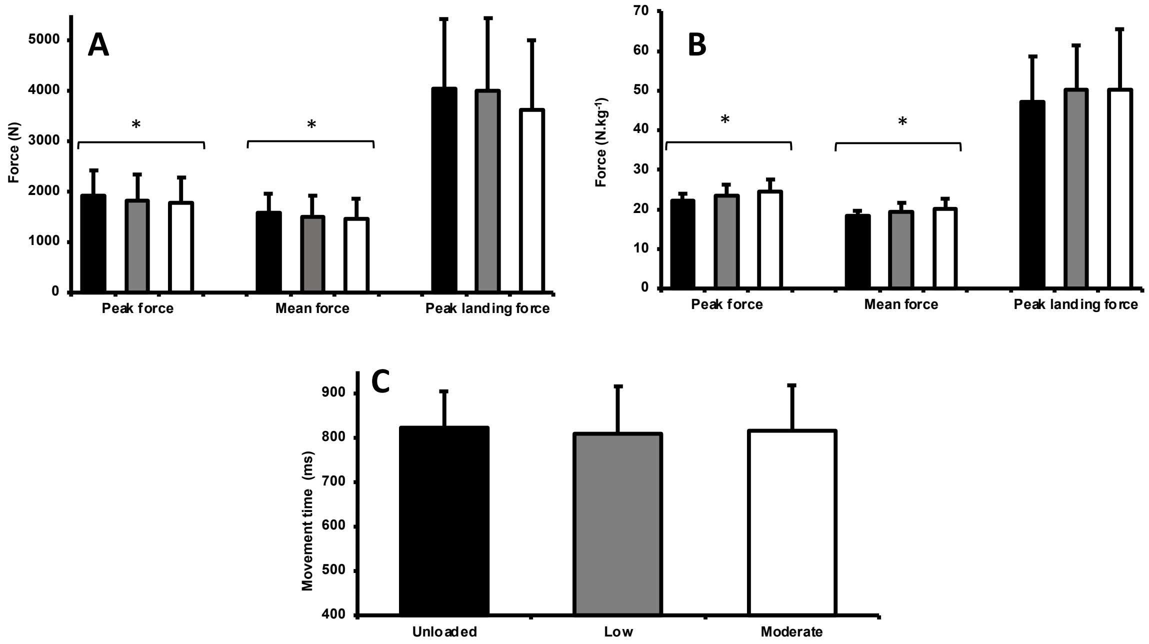

Figure 3. Selected countermovement jump variables. The black, grey and white bars represent the unloaded, low and moderate conditions, respectively. *, differences between all conditions ($P<0.05$).

Table 1. Analysis of variance (*F*), t-test (*t*) and effect size (ES) statistics for variables assessed during countermovement jump performance.

Variable			**Unloaded vs low**			**Unloaded vs moderate**			**Low vs moderate**		
	F	*P*	*t*	*P*	ES	*t*	*P*	ES	*t*	*P*	ES
Peak velocity (m/s)	3.6	0.038	2.6	0.020	0.45	2.2	0.037	0.51	0.3	0.799	-
Mean velocity (m/s)	0.0	0.969	-	-	-	-	-	-	-	-	-
Peak force (N)	47.2	<0.000	5.9	<0.000	0.18	8.7	<0.000	0.28	3.9	0.001	0.09
Peak force (N/kg)	20.4	<0.000	3.2	0.005	0.55	5.1	<0.000	0.91	-4.7	<0.000	0.34
Mean force (N)	64.1	<0.000	6.8	<0.000	0.19	10.1	<0.000	0.30	5.1	<0.000	0.10
Mean force (N/kg)	14.7	<0.000	-3.5	0.002	0.54	4.2	0.001	0.88	-0.3	0.006	0.33
Movement duration (ms)	1.5	0.229	-	-	-	-	-	-	-	-	-
Peak landing force (N)	3.0	0.064	-	-	-	-	-	-	-	-	-
Peak landing force (N/kg)	2.1	0.139	-	-	-	-	-	-	-	-	-
RSI_{mod} *(au)*	13.8	<0.000	-3.6	0.002	0.54	-5.1	<0.000	0.74	-1.9	0.072	-
Flight time (ms)	35.8	<0.000	-6.2	<0.000	0.59	-6.9	<0.000	0.92	4.0	<0.001	0.34

RSI_{mod}, reactive strength index modified.

Table 2. Relationship between the stretch of the band and selected countermovement jump variables. Values are presented with ± 95% confidence

		Low	**Moderate**
Peak velocity (m/s)	*r*	0.28 ± 0.37	0.22 ± 0.38
	P	0.245	0.343
Mean velocity (m/s)	*r*	0.12 ± 0.43	0.11 ± 0.42
	P	0.632	0.659
Peak force (N)	*r*	0.20 ± 0.39	0.21 ± 3.9
	P	0.41	0.381
Mean force (N)	*r*	0.20 ± 3.9	0.20 ± 0.39
	P	0.391	0.41