©Journal of Sports Science and Medicine (2013) **12**, 122-129
http://www.jssm.org

Research article

Ground Reaction Forces and Loading Rates Associated with Parkour and Traditional Drop Landing Techniques

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Abstract
Due to the relative infancy of Parkour there is currently a lack of empirical evidence on which to base specific technique instruction upon. The purpose of this study was to compare the ground reaction forces and loading rates involved in two Parkour landing techniques encouraged by local Parkour instructors and a traditional landing technique recommended in the literature. Ten male participants performed three different drop landing techniques (Parkour precision, Parkour roll, and traditional) onto a force plate. Compared to the traditional technique the Parkour precision technique demonstrated significantly less maximal vertical landing force (38%, $p < 0.01$, ES = 1.76) and landing loading rate (54%, $p < 0.01$, ES = 1.22). Similarly, less maximal vertical landing force (43%, $p < 0.01$, ES = 2.04) and landing loading rate (63%, $p < 0.01$, ES = 1.54) were observed in the Parkour roll technique compared to the traditional technique. It is unclear whether or not the Parkour precision technique produced lower landing forces and loading rates than the Parkour roll technique as no significant differences were found. The landing techniques encouraged by local Parkour instructors such as the precision and roll appear to be more appropriate for Parkour practitioners to perform than a traditional landing technique due to the lower landing forces and loading rates experienced.

Key words: Kinetics, absorption, forefoot, roll.

Introduction

Born in France, Parkour involves practitioners (called traceurs) training to overcome obstacles in their path by adapting their movements (Typically running, climbing, jumping, vaulting and quadrupedal movement) to the given environment for the purpose of reaching somewhere or something or escaping from someone or something. Such a pursuit encompasses the ethos - “be strong to be useful”.

Parkour is a new physical discipline and philosophy that requires a huge emphasis on safe landing strategies. Landing actions make up a significant portion of many modern day sports (McNair et al., 1999; Tillman et al., 2004b) and in activities of daily living (McNitt-Gray, 1991) such as human locomotion (Kovacs et al., 1999). Incorrect landings account for one of the most common causes of injury in court based sports (Hume et al., 2000) with the knee being shown to be the most frequent injury location due to the sudden decelerations (Boden et al., 2000; Noyes et al., 1983). Landing decelerations result in far greater vertical ground reaction forces (vGRF) than those experienced during cyclical movements such as walking and running (Zhang et al., 2008). Ground reaction force is an indicator of the intensity of stress on the human system during ground contact (McClay et al., 1994). When GRFs are too great, the musculoskeletal system is unable to disperse the forces, thus increasing the potential for injury (Dufek et al., 1990; Irmischer et al., 2004; McNitt-Gray, 1991) and various joint pathologies (Elvin et al., 2007). These risks may potentially be even more so if the magnitude of loading rate (the speed at which forces impact the body (Bauer et al., 2001; Crossley et al., 1999) is high due to shock absorption and force distribution occurring in the musculoskeletal system during landing, depending on the magnitude of loading rate being insufficient (Ricard et al., 1990).

In the past, researchers have looked at lower extremity kinematics during drop landing, such as degrees of flexion in the knee, ankle, and hip (Blackburn et al., 2009; Cortes et al., 2007) and varus and valgus (mediolateral) motion of the knees (Ford et al., 2003; Jackson et al., 2010). Studies have also investigated kinetic variables during landing such as peak vGRF (Ricard et al., 1994), time to peak vGRF (Caulfield et al., 2004), loading rate (Bauer et al., 2001; Decker et al., 2003; Ricard et al., 1990), and muscular activity via EMG (Tillman et al., 2004a). Furthermore, other studies have investigated drop landing comparisons between males and females (Fagenbaum et al., 2003; Salci et al., 2004; Yu et al., 2006), adults and children (Swartz et al., 2005), unilateral and bilateral (Tillman et al., 2004b), athletes and non-athletes (McNair et al., 1999), different sports (Bressel et al., 2005), feedback and non-feedback groups (Cronin et al., 2008; McNair et al., 2000; Prapavessis et al., 2003; Walsh, 2007), landing heights (Yeow et al., 2009; Zhang et al., 2008) and different landing surfaces (McNitt-Gray et al., 1994).

A number of different landing techniques based on their utilization in the sporting world have been investigated. The two major strategies are toe-heel (forefoot) and heel-toe (rear-foot), though athletes tend to have their own unique style of landing depending on the demands of the sport and their particular preference (Cortes et al., 2007). The rear-foot strategy is most common in moderate speed running tasks and has been said to be a better method for dissipating landing forces compared to a flat foot landing (Dufek et al., 1990). The forefoot strategy, is referred to as the “real jump-landing” by Schot and Dufek (1993) due to its commonality in jump landings. This landing technique (referred to as the traditional technique in this study) is very common in sports such as basketball and volleyball and has been deemed as an important method for landing (Bressel et al., 2005). This may be due to forefoot first landings being reported to demonstrate

Received: 19 August 2012 / Accepted: 10 January 2013 / Published (online): 01 March 2013

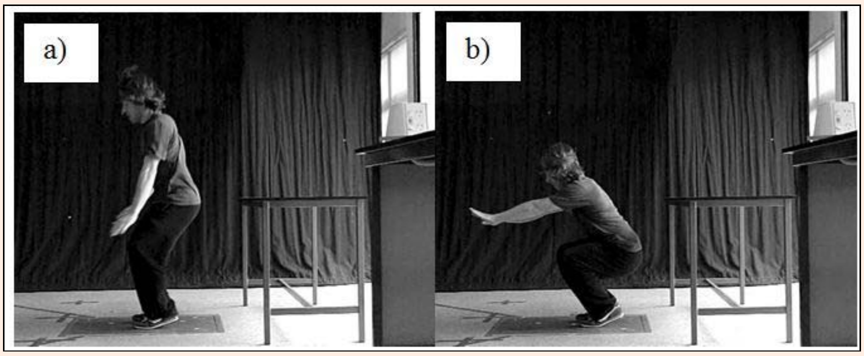

Figure 1. **Parkour precision landing; a) Landing phase, b) Cushioning phase.**

greater degrees of knee flexion allowing the knee to absorb energy for longer (Cortes et al., 2007) or the energy absorption and shock attenuation carried out by the loading of musculature around the ankle (Gross et al., 1988). Maximal vGRFs during forefoot contact of a toe-heel landing strategy in children and in female volleyball players have been reported to be less than during rear-foot contact (Bauer et al., 2001; Cronin et al., 2008). Forefoot (without heel contact) drop jumps resulted in higher energy absorption than heel-toe (Kovacs et al., 1999).

The widely practiced methods of landing in Parkour involve A) Parkour precision: landing on the forefoot or balls of the feet, bending the knees to absorb impact without any varus or valgus movement of the knees and using the arms to counterbalance the movement and B) Parkour roll: a shoulder roll in the direction of travel, leading with one side of the body and finishing on the opposite side of the body. These rolls are initiated out of an initial forefoot landing and used when landing from height (especially when higher than the individual's height). The landing strategies employed by traceurs are advocated by instructors and practitioners alike throughout the world. Unfortunately, due to the relative infancy of Parkour there is a lack of literature surrounding the pursuit and thus no normative data in which to base specific technique instruction upon. The purpose of this study was to compare the ground reaction forces and loading rates involved in two Parkour landing techniques (Precision and Roll) encouraged by Parkour instructors and a traditional landing technique recommended in the literature. It was hypothesized that both Parkour techniques would result in lower vertical ground reaction forces and loading rates, with slower times to maximal vertical force than the traditional technique, based on the dissipation of forces involved in both respective movement patterns. It was also hypothesized that the Parkour roll would result in lower vertical ground reaction forces and loading rates, with slower times to maximal vertical force than the Parkour precision landing.

Methods

Participants

Ten male New Zealand based traceurs were recruited for this study (see Table 1). All participants had participated in Parkour training for at least two years and were injury free to the lower extremity at the time of testing. Participants gave informed written consent before participating in this study as approved by the Institute's Research Ethics Committee where the study was conducted.

Table 1. **Traceur characteristics.**

	Mean (SD)
Age (yrs)	20.5 (4.8)
Height (m)	1.80 (.07)
Mass (kg)	74.5 (11.3)
Training (yrs)	2.9 (1.0)

Procedures

A time series experimental design where participants acted as their own control was incorporated in this study (Hopkins, 2000). Participants were required to perform three types of drop landings from a platform as per the following: *Parkour precision landing* (see Figure 1); a landing used by traceurs when landing on the top of an obstacle (e.g. rail, wall, branch, etc.). This landing involves a forefoot contact with no rear-foot contact. The precision is accurately named, as the obstacles that traceurs land on are often quite small and require great accuracy to land on. *Roll landing* (see Figure 2); a landing used by traceurs when dropping from height onto a surface with sufficient even space (e.g. ground). This landing involves an initial forefoot landing immediately followed by a shoulder roll leading with one side of the body and finishing on the opposite side of the body. *Traditional landing* (see Figure 3); a landing strategy typically used by sporting persons (e.g. basketball and volley ball players) and the general public which involves landing on the forefoot and lowering to the rear-foot (Bressel et al., 2005; Dufek et al., 1990).

During the testing session participants completed a thorough warm up [involving five minutes of non-weight bearing activity (cycling) followed by self directed dynamic stretching]. A familiarization period of three attempts at each drop landing was employed following the warm-up. Participants performed five trials of each block randomized drop landing, to reduce the likelihood of a biased effect (difference). Five trials were used based on recommendations from Bates et al (1992) that state that five trials are required to achieve adequate statistical power when recording data from 10 participants.

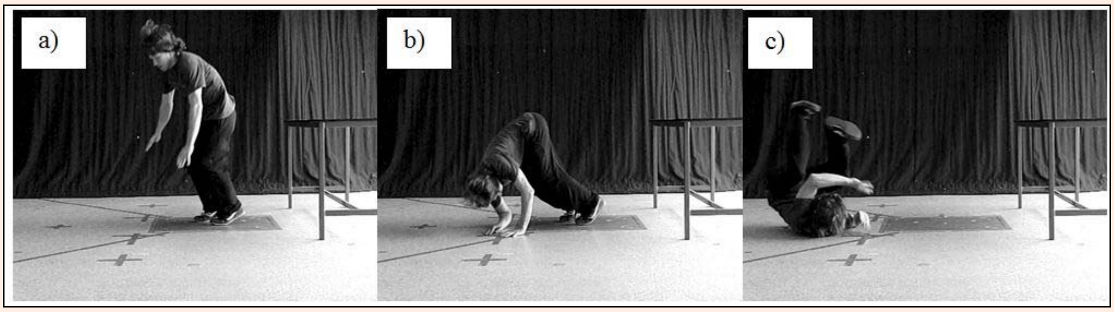

Figure 2. Roll landing; a) Landing phase, b) Entry phase, c) Exit phase.

Participants performed all drop landings from a platform 0.75m in height situated 0.15m away from a single force plate (Kistler, Switzerland) embedded in the laboratory floor. The force plate sampled at 500 Hz and was used to quantify all kinetic variables. Data was collected using BioWare 4.1 software.

Dominant leg, or leading leg as it will be referred to in this study, was determined by having participants perform several drop landing trials without any instruction. Leading leg refers to the moving leg, whereas the non-dominant leg refers to the leg used for support (Sadeghi et al., 2000). The leading leg was considered to be dominant. The drop landing protocol for all three landings was as follows: Standing with non-dominant leg locked in a vertical position, participants stepped out with the leading leg and dropped down onto the force plate and performed the specified drop landing. The leading leg for each traceur was used for all trials and all roll landings were performed over the preferred shoulder. Participants were instructed to perform each trial of each landing as softly and as controlled as possible. Rest periods of 30 seconds between trials and one minute between landing scenarios were employed.

Data analysis

BioWare software was used to extrapolate the force data from the force plate. Vertical GRF was low-pass filtered using a fourth-order Butterworth filter with a 50 Hz cut-off frequency (Johnson et al., 2001). All sets of data were exported to MS Excel 2007 in order to derive the dependent variables of interest. The variables of interest were defined and calculated as follows: *Maximal vertical force* – the highest recorded vertical force during landing, calculated via the force plate. The magnitude of the landing force was divided by the individual's body weight in Newtons to allow for the expression of landing force as body weights (BW). This normalization allowed for comparisons between individuals to be made. Within session reliability analyses revealed the typical error as a coefficient of variation % for maximal vertical force to be 14.6, 7.3 and 8.1% for the traditional, precision and roll tasks respectively. *Time to maximal vertical force* – the time taken to achieve the highest vertical force, calculated by subtracting the time at maximal vertical force by the time of initial foot contact (where the vertical force exceeded 50N). Within session reliability analyses revealed the typical error as a coefficient of variation % for maximal vertical force to be 18.0, 33.3 and 38.4% for the traditional, precision and roll tasks respectively. *Loading rate* - the speed at which forces impact the body, calculated by dividing the maximal vertical force by the time to the maximal vertical force (Bauer et al., 2001; Crossley et al., 1999). Within session reliability analyses revealed the typical error as a coefficient of variation % for maximal vertical force to be 32.5, 46.5 and 43.7% for the traditional, precision and roll tasks respectively.

Statistical analysis

Comparisons were made between all landings using the methods of Hopkins (2006). This involved the use of an MS Excel 2007 spreadsheet that allowed a post only crossover analysis to be performed. The spreadsheet provided statistical outcomes representative of *p* values (*p* values of less than 0.05 were considered to be statistically

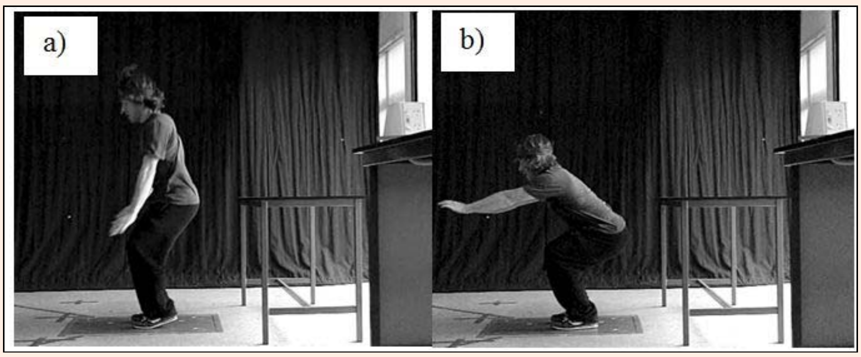

Figure 3. Traditional landing; a) Landing phase, b) Cushioning phase.

Table 2. Mean (SD) variable results for all three drop landings.

	Precision	Roll	Traditional
mVF (BW)	3.2 (.5) *	2.9 (.2) †	5.2 (1.2)
Time to mVF (s)	.077 (.053) *	.080 (.031) †	.044 (.015)
Loading rate (BW/s)	83.3 (80.1) *	64.1 (59.8) †	154.3 (96.3)

mVF = maximal vertical force, BW = body weight.
* and † = significant difference (p < 0.05) compared to traditional.

significant), percentage differences, 90% confidence intervals of the percentage differences, Cohen's effect sizes and qualitative inferences to be presented-. Specifically, differences in landing scenarios were expressed as a percentage via analysis of log-transformed values using natural logarithms. Logarithmic transformation allows for uniformity of error thus this strategy was used to reduce bias arising from non-uniformity of error raw values (differences) of the variables of interest. Inferential statistics were based on interpretation of magnitude of effects (differences), as described by Batterham and Hopkins (2006). The likelihood of the differences (effect unit) was interpreted using the Cohen scale of magnitudes for the standardized differences in the mean. The Cohen scale is divided into different effect sizes which are used to quantify the differences between conditions (Hopkins et al., 2009). To make inferences about the true values of the percentage differences and effect sizes between landing scenarios the uncertainty in the percentage differences and effect sizes were expressed as 90% confidence intervals and as likelihoods that the true value of the difference is substantial (Batterham et al., 2006). A difference was deemed unclear if its confidence interval of the effect statistic overlapped substantially positive and negative values and the threshold for the smallest worthwhile effect, otherwise, when a result was above the threshold for the smallest worthwhile effect the results could be given as: 0 – 0.2 trivial; 0.2 – 0.6 small; 0.6 – 1.2 moderate; 1.2 – 2.0 large; 2.0 – 4.0 very large. An effect size of 0.2 was chosen to be the smallest worthwhile difference in the means in standardized (Cohen) units as it gave chances that the true effect would at least be small (Cohen, 1990).

Results

Findings for all three landing techniques presented as Mean ± SD can be viewed in Table 2. Significant differences were found for all variables of interest between the Parkour precision trials and the Traditional trials (see Table 3) and between the Parkour roll trials and the Traditional trials (see Table 4). No significant differences were found between Parkour precision and Parkour roll trials (see Table 5). Specifically, Parkour precision and Parkour roll trials resulted in significantly (p = 0.0003 and p = 0.0001 respectively) lower (-38.4% and -42.9% respectively) maximal vertical force during the landing than in traditional trials showing very large to large negative effect sizes, respectively. Parkour precision and Parkour roll trials resulted in significantly (p = 0.0039 and p = 0.0092 respectively) slower (60.6% and 78.6% respectively) times to maximal vertical force than in traditional trials showing small to moderate and small to large effect sizes, respectively. Parkour precision and Parkour roll trials resulted in significantly (p = 0.0020 and p = 0.0010 respectively) lower (-54.2% and -62.8% respectively) loading rates than in traditional trials showing large to moderate and very large to moderate effect sizes, respectively.

Discussion

The aim of the present study was to quantify the magnitudes of maximal vertical force, time to maximal vertical force, and loading rates present in two Parkour based landing techniques and compare those results with those of a more traditional technique found in the literature. It was hypothesized that both the Parkour precision and the Parkour roll techniques would result in less maximal vertical force, lower loading rates, and slower times to maximal vertical force than the traditional technique and that the same trend would be seen for the Parkour roll over the Parkour precision. The findings of this study support the main hypothesis with significant differences found between both Parkour landing techniques and the traditional technique. However, no significant differences were found between Parkour precision landings and Parkour roll landings.

Maximal vertical force

Ground reaction force is an indicator of the intensity of stress on the human system during ground contact (McClay et al., 1994). Based on the findings of this study it would appear that the Parkour landing strategies are less stressful during ground contact compared to that of the traditional landing strategy. Specifically, the maximal vertical force for the Parkour precision (3.2 BW) and

Table 3. Differences between Parkour precision landings and traditional landings (precision – traditional), including qualitative inferences about the effects of those differences.

	p value	Diff in means as Percentage (%)	Diff. in means as % 90% confidence levels lower	upper	Cohen ES	Qualitative inferences of ES
mVF (BW)	.0003*	-38.4	-47.1	-28.2	-1.76	very large-large
Time to mVF (s)	.0039*	60.6	28.2	101.1	.80	small-moderate
Loading rate (BW/s)	.0020*	-54.2	-67.2	-36.0	-1.22	large-moderate

mVF = maximal vertical force, BW = body weight, Diff. = difference, ES = effect size, * = statistically significant difference (p < 0.05).

Table 4. **Differences between Parkour roll landings and traditional landings (roll – traditional), including qualitative inferences about the effects of those differences.**

	p value	Diff in means as Percentage (%)	Diff. in means as % 90% confidence levels lower	upper	Cohen ES	Qualitative inferences of ES
mVF (BW)	.0001*	-42.9	-50.5	-34.1	-2.04	very large-large
Time to mVF (s)	.0092*	78.6	29.5	146.5	.99	small-large
Loading rate (BW/s)	.0010*	-62.8	-74.5	-45.6	-1.54	very large-moderate

mVF = maximal vertical force, BW = body weight, Diff. = difference, ES = effect size, * = statistically significant difference ($p < 0.05$).

Parkour roll (2.9 BW) landing techniques were substantially lower than that experienced during the traditional landing (5.2 BW). Previous research has investigated vertical ground reaction forces (vGRF) during a traditional landing across a range of sports (Blackburn et al., 2009; McNitt-Gray, 1993; Zhang et al., 2008). These studies have shown a wide spectrum of findings due to the participant populations, landing techniques, and testing protocols. Nonetheless their findings offer a realm of normative data from which the current studies traditional landing force data concurs. For example, testing of physically active males have shown maximal vertical forces of ~7 BW dropping from a height of 0.75 m with no specific landing technique (Zhang et al., 2008). Furthermore, males landing with their preferred landing technique from a height of 0.60 m exhibited maximal vertical forces of ~4 BW (Blackburn et al., 2009). Testing of sport specific individuals has revealed maximal vertical forces of ~6 BW from gymnastics when dropping from a height of 0.72 m using their preferred technique (McNitt-Gray, 1993). The maximal vertical force for the Parkour precision and Parkour roll were substantially lower than all the findings of the previous studies mentioned, even those landing from heights 40% lower that that employed in the current study. Specifically, the maximal vertical forces of the Parkour techniques were less than half those found by Zhang et al., (2008) when dropping from the same height. An explanation for lower forces demonstrated during the Parkour techniques may be the differences in landing posture between the Parkour and traditional techniques. Higher landing impact forces are associated with more erect postures during ground contact (Blackburn et al., 2009; Devita et al., 1992). In comparison to the Parkour techniques it is feasible that during a traditional technique the individual would adopt a more erect posture at ground impact. However, no visual data was collected in this study to confirm such an assumption. Nonetheless, based on the protocols employed for the Parkour techniques it was anecdotally evident that during the precision and roll substantial amounts of knee flexion and trunk flexion were occurring. Improved absorption of impact forces during landing has been reported in individuals demonstrating greater trunk flexion (Blackburn et al., 2009), greater hip flexion and greater knee flexion during a landing task (Swartz et al., 2005). It is evident from the aforementioned studies that further insight into landing kinetics from a kinematic perspective could be derived from recorded joint angles during the landing techniques utilized by their participants. Future research should include video recording to investigate the kinematic characteristics that are associated with the kinetic concepts of Parkour landing techniques.

The results of the current study indicate both Parkour precision and Parkour roll landings reach maximal vertical force in a mean time of 80 ms (0.08 s), whereas the traditional landing had a mean time of 40 ms (0.04 s). Literature suggests the neuromuscular system requires around 50ms to react to a stimulus appropriately and that prior to this time the system must rely on muscle pre-activation for shock attenuation in the first 50 ms of landing (Ricard et al., 1990). This suggests that landings that have maximal vertical forces occurring within 50 ms of landing (passive forces) may cause musculoskeletal damage (Ricard et al., 1990). For example, in volleyball spike landings the time to maximal vGRF occur from 10ms (0.010 ± 0.001 s) to 45 ms (0.045 ± 0.009 s) after initial ground contact (Cronin et al., 2008) while individuals with functional instability of the ankle have shown times of 40ms (0.04 ± 0.01 s) versus a control group with times of 50 ms (0.05 ± 0.007 s) seconds when dropping onto one leg from a 0.40 m platform (Caulfield et al., 2004). Based on the findings of the current study and those of literature it is plausible that the Parkour techniques allow the neuromuscular system more time (80ms vs. 50ms) to respond to the forces generated upon landing than the traditional method. Such a strategy employed by the neuromuscular system during the Parkour techniques may prove advantageous for traceurs in minimizing injury risk. Future studies would benefit from measuring muscle pre-activation along with time to maximal vertical force in Parkour landings to investigate whether the pre-activation of the lower extremities in those landings provide adequate shock absorption.

Table 5. **Differences between Parkour precision landings and Parkour roll landings (roll – precision), including qualitative inferences about the effects of those differences.**

	p value	Diff in means as Percentage (%)	Diff. in means as % 90% confidence levels lower	upper	Cohen ES	Qualitative inferences of ES
mVF (BW)	.1707	-7.3	-15.7	1.8	-.28	moderate-trivial
Time to mVF (s)	.5825	11.2	-21.0	56.6	.18	unclear
Loading rate (BW/s)	.3284	-18.7	-43.7	17.4	-.32	unclear

mVF = maximal vertical force, BW = body weight, Diff. = difference, ES = effect size.

The rate at which forces are absorbed by the lower extremity may be more important than maximal vertical for measuring the severity of landing impact (Woodard et al., 1999). For this reason the current study adopted this measure as a variable of interest. Interestingly, loading rates for both Parkour techniques (83.3 ± 80.1 BW/s for Parkour precisions, 64.1 ± 59.8 BW/s for Parkour rolls) were significantly lower (approximately 50%) than those of the traditional technique (154.3 ± 96.3 BW/s) assessed in this study. Our traditional loading rate values are similar to those reported for male (96.18 BW/s) and female (162.11 BW/s) athletes that performed a drop landing from a height of 0.60 m (Decker et al., 2003). Loading rate magnitudes calculated for the Parkour techniques in the current study were similar but slightly higher than those present in normal running patterns (60 BW/s) of healthy university students (Ruano et al., 2009) and those during high impact aerobic dance (43 BW/s) (Ricard et al., 1990).

It is not surprising that the loading rate magnitudes calculated from the Parkour techniques were lesser than the traditional technique in this study as the traditional technique elucidated higher maximal vertical forces at shorter durations (time to maximal vertical force). Such outcomes maximize the chance of an increased loading rate due to the calculation of loading rate (force ÷ time to force). What is of more interest is the potential benefit of performing Parkour techniques over the traditional technique from a drop landing height of 0.75 m to minimize loading rate. Research has implicated a high loading rate as a contributor to soft and hard tissue pathology of the lower extremities (Woodard et al., 1999). The fact that traceurs are incorporating techniques currently in their training practice that may be safer (low loading rates) for them may prove beneficial however it is unclear whether any of these loading rates or techniques would cause injury over time. It is recommended that researchers investigate the longitudinal associations between loading rates in Parkour landings and lower extremity injury occurrences during Parkour practitioning.

It is clear that the Parkour landing techniques are more favourable than the traditional technique in all variables of interest measured in this study. However, it is not clear as to which Parkour technique is the more appropriate to use due to the moderate-trivial effect sizes between the two techniques. Although this study found such effects there is a trend in the data that shows some benefit for utilization of the Parkour roll over the Parkour precision. It is not unreasonable to speculate that the higher the drop, the greater the trends towards a Parkour roll being a safer landing than a Parkour precision. Such a view point has been adopted by the Parkour community. Further understanding of when it would be most appropriate to perform a Parkour roll over the Parkour precision is needed. Research investigating similar variables of interest as those measured in this study during varying heights to perform drop landings from would be advantageous for the Parkour community. Such an investigation would further aid in the prescription of training strategies for traceurs.

A variety of limitations of the current study should be acknowledged. For instance Parkour, by its nature is variable and traceurs are as variable as the environments that they train in. This goes the same for the training methods used by traceurs and the techniques they choose to devote their time to. These different styles of training may cause disparities between the results causing inadequate reflections of time spent training on ability to perform Parkour landing techniques soundly. Despite the variable nature of Parkour, some techniques have specific constraints recommended by instructors and practitioners for safety purposes. Landing is one of these techniques. On these grounds, it may be possible that the landing techniques used by traceurs are too ingrained to be able to land traditionally in the same manner as other sports persons or the general public. It may be appropriate for future research in this area to focus on comparing preferred landings techniques between traceurs and practitioners of another activity. Based on this limitation it is suggested that enthusiasts from other sporting pursuits cautiously consider the applicability of this study's findings to landing strategies to be performed in the respective sport of interest.

A methodological limitation of the current study concerns the step off protocol carried out by traceurs prior to all landing scenarios. The step off protocol utilized in this study was for the purpose of standardization however it should be noted that this protocol is atypical to that which is used when participating in Parkour. Varying degrees of joint flexion in the stance leg and lead leg would typically be adopted by traceurs however if self selected step off strategies were allowed in this study it is highly likely that discrepancies in force data would have arisen due to inter subject step off variation and possibly confounded the results slightly.

Conclusion

Parkour precision and Parkour roll landings were found to be safer than a traditional landing technique, resulting in lower maximal vertical forces, slower times to maximal vertical force and ultimately lesser loading rates. Based on the findings of this study, it is recommended that traceurs utilize the precision or roll technique when performing landings in Parkour. Though unclear the Parkour roll appears to be more appropriate (safer) to utilize than the Parkour precision however more research is required to validate such an assumption. Overall the results of the current study provide new insight into landing techniques utilized by a new population of individuals, however, whilst the outcomes of this study are relevant to traceurs the landing techniques used may be beneficial for landing by non-Parkour practitioners in everyday life and may be applicable for some athletes in other sports. Such a proposition encourages avenues for future investigation.

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Key points

- Parkour precision and Parkour roll landings were found to be safer than a traditional landing technique, resulting in lower maximal vertical forces, slower times to maximal vertical force and ultimately lesser loading rates.
- Parkour roll may be more appropriate (safer) to utilize than the Parkour precision during Parkour landing scenarios.
- The Parkour landing techniques investigated n this study may be beneficial for landing by non-Parkour practitioners in everyday life.

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