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What makes parkour unique?

A narrative review across miscellaneous academic fields.

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ABSTRACT

Parkour is a growing sport that mostly involves jumping, vaulting over obstacles, and climbing in a non-dedicated setting. The authors gathered all known relevant literature across miscellaneous academic fields in order to define parkour with regards to other sports disciplines.

Parkour is a lifestyle sport, and as such provides an alternative to mainstream ones, away from strict rules, standardized settings, and necessary competitions. Traceurs (parkour adepts) consider the city as a playground and as an outlet for their creativity, but they also have a strong taste for hard and individualized challenges. They usually train on non-specific

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structures, at ground level. Although their social background is not clear, they are mostly young and male.

Traceurs are stronger than recreational athletes, especially in eccentric exercises. However, their endurance skills may be below average. One of the core specificities of parkour is its precision constraint at landing, which turns a standing long jump into a precision jump, regulated in-flight so as to prepare for landing. The running precision jump follows the same landing pattern, and its flight phase contrasts with long jump techniques. Injuries, which are not more frequent than in other sports, often occur at reception and on lower limb extremities. This risk is coped with targeting the landing area with the forefoot instead of letting the heel hit the ground like in gymnastics, or with rolling in order to dissipate the impact.

Overall, parkour focuses on adaptability to new environments, which leads to specific techniques that have not yet been extensively addressed by the literature.

Key-words: free-running, biomechanics, physiology, landing, precision, lifestyle sport

KEY-POINTS

Parkour is well in line with modern lifestyle sports, that challenge our traditional view of sports as rule-based, set in a dedicated environment, with specialized equipment.

Precision landing is one of the key components of parkour, which involves adapting posture during later phases of the jump in order to make up for potential errors at take-off.

Parkour adepts (traceurs) are landing experts, and must learn specific ways of softening impacts in order to prevent injury. Incidentally it makes them particularly good at eccentric exercises.

I. Introduction – What is parkour?

Parkour is a physical activity born in the early 1990s in the suburbs of Paris, France, that involves using only the body to overcome obstacles. Some call it a training method [1], or a way of getting from point A to point B [2] through complex, three dimensional environments [3]. It may involve running, jumping, vaulting, climbing, balancing, grabbing, or any other means to get from one point to another. “Free-running” and “art of displacement” share a common origin with parkour [2]. A parkour adept is called a “traceur”, from the French verb “tracer” which means both going fast, and drawing a line (i.e., from one point to another).

Parkour is recent in its contemporary athletic and social form, however overcoming obstacles is a natural feat of all living beings, and parkour has been compared to animal movement [3–6], or to movie stunts such as Jackie Chan’s [7]. Describing parkour, Angel [2] states: “There are elements of child’s play within the spatial awareness and actions; the approach to the training is similar to the discipline found in martial arts; the levels of risk involved has parallels with solo free-climbing, the ability to adapt and seek out opportunities in the environment is reminiscent of ‘the art of escape’, and the passing over of obstacles connects back to the military obstacle course, ‘le parcours du combattant.’” The track and field and gymnastics international federations have taken an interest in parkour, especially the latter, which engaged in a very controversial appropriation of the discipline in 2018 [8].

Several authors have studied very specific aspects of parkour under different academic perspectives, which gives a rather fragmentary understanding of the discipline. This article is the first literature review conducted about parkour, and aims to characterize the profile of its practitioners (called traceurs) through an extensive, multidisciplinary review of the literature. ScienceDirect, Pubmed and Google scholar databases have been screened for the term “parkour”, without restriction on publication date. Both social aspects and life science aspects have been examined and compared to those of other sports, in order to give a broad insight on the discipline and to help further understanding the singular position of parkour.

II. Social sciences aspects

Most of the social sciences studies about parkour have used qualitative data. Some have focused on documentary analysis [9,10] or interviews [2,9,11,12]. On their own, these methods

are insufficient, because what is shown and said about parkour in the media and by practitioners is often contradictory and does not always reflect the in-situ practice of parkour. Ethnographies, usually with participant observation [13–17] allow for a more situated and embodied analysis.

However, this focus on qualitative research also means that there is a dearth of systematic quantitative data.

II. 1. A lifestyle sport

A lifestyle sport is an activity that “either ideologically or practically provides alternatives to mainstream sports and to mainstream sport values.” [18] Some commentators have argued that they may better be conceptualized as a form of play with an important part of artistic sensibility [19]. They are often called extreme sports, although this tends to be the way mainstream media and marketers see them rather than the participants themselves [18]. More importantly, these sports involve a particular “style of life”, that gives their adepts a particular and exclusive social identity [19]: they show high commitment in time and/or money, promote an hedonistic way of life, and tend to reject regulation and control, and to be critical of competitions [20]. Parkour fits perfectly with Suits’ definition of game: “a voluntary attempt to overcome unnecessary obstacles” [21], and less so with Borge’s understanding of sport: “an extra-ordinary, unnecessary, rule-based, competitive, skill-based physical activity” [22]. Indeed, there are no written rules in parkour apart from staying safe (hence the motto “être et durer”, French for “to be and to last” borrowed from an elite regiment of the French army) and respecting each others and the environment; and until recently, one of the few things the originators agreed upon was that parkour is non competitive [23]. As in other lifestyle sports, the performance is never fixed or determinate, but is in a state of flux and change [24].

Behind parkour is a philosophy inspired by Hébert’s “natural method”, that he developed after having met indigenous people whose bodies were “splendid, flexible, nimble, skillful, enduring, resistant and yet they had no other tutor in gymnastics but their lives in nature” [25]. Thus, parkour is an outdoor activity that is practiced without any equipment nor any protective gear, in the most natural way possible. This leads traceurs to appreciate their environment in a unique way [9], and to see obstacles as opportunities for improvement, as much in a context of sports as in day-to-day life. Hébert’s motto, “be strong to be useful”, resonates with traceurs’ ambitions to see their practice as a tool. The founders of parkour, i.e. the 9 pioneers who started

to develop the activity in the 90's, were as deeply influenced by real heroes of war and firefighters, as by superheroes from comic books or Japanese animes [2]. As a consequence, it seems like parkour improves adolescents' self-esteem [26]. Through the exploration of movement, Parkour manifests as an extroverted way of expression, yet one that leads to a process of self-examination of one's psychological and emotional state [27].

The parkour community has been frequently described as mostly non-competitive, non-hierarchical, supportive and inclusive, fostering an atmosphere of collaboration [12,13,28–31]. Hence as a lifestyle sport, parkour could be a good candidate with “hard to reach” people, who are not attracted to mainstream, traditional, competitive sports [28–32].

II. 2. Demographics

Social class and/or occupation of the parkour practitioners has not been systematically studied. The founders were second generation male immigrants, living in the suburbs of Paris, France [33]. Parkour has now spread worldwide, to the point that an international federation, Parkour Earth [8], has been created to include governing bodies from countries around the globe. As a consequence, the demographics of parkour have shifted. According to Gibout & Lebreton [14], parkour tends to attract participants from lower social class than other urban sports, where participants usually come from middle or upper intellectual classes. But Kidder [34] found that while traceurs were socially and ethnically mixed, there was a majority of white, middle class men, in their late teens to early 20s. Prévitali et al. [17] also found that traceurs seemed to come from “wealthy” social classes. Janeckova et al. found no correlation between socio-economical status and participation in parkour practice among school aged kids in Czech Republic [32]. The data regarding social class is therefore inconsistent, hence further research is needed in this area.

Studies using online questionnaires support that traceurs are young and male (Table 1) [35–38]. As a comparison, a survey carried out among 27.919 participants in the 28 states of the European Union reported in 2014 that the sex gap in overall sports participation is strongest between ages 15-24 years old [39]. In that age group, it amounts to 42% of female participation (numbers extrapolated from [39]), in contrast to the 15% of female traceurs among the French Parkour Federation [40]. Empirical research shows that parkour is facing some contradictory challenges: despite it strives for more inclusivity for all, and does not embrace some central aspects of traditional sporting masculinity such as the win-at-all cost ethos, for some women

parkour spaces are nonetheless perceived as alienating, and all women environments have provided ‘safer’ spaces for entry [41].

Parkour is a young discipline and its demographics are still evolving with time. However, the available evidence suggests that the parkour population is similar to that of other urban sports such as skateboarding [42], but more detailed comparisons would require larger scale studies. It would also be interesting to compare how demographics differ regarding the country of residence, as well as depending on whether or not the considered population is enrolled in an organized club.

Article	n	Sex (% male)	Age
Wanke et al. [38]	266	96%	18 (average)
Merritt & Tharp [37]	277	87%	22 (average)
Grosprêtre & Lepers [35]	130	88%	19.4± 4.3 (average)
Holzmüller & Braumüller [36]	458	87%	68.1% between 20-29

Table 1. Age and sex gap in parkour.

II. 3. Parkour and transgression

Numerous papers focus on transgressive and political aspects of parkour, which has often been seen as a form of critique of urban society. Parkour can be viewed as an attempt towards unrestricted movement in an environment designed to restrict movement: walls are climbed, barriers are vaulted over, and obstacles are seen as opportunities [9]. Through this creative misuse of the city [43], urban spaces can be viewed as spaces of possibilities and creativity. For Atkinson [13], parkour is an “anarcho-environmentalist” practice. By reinterpreting the “techno-capitalist” environment for their own needs, traceurs make themselves at home in it. Parkour uses urban space in a non-commodified way. They create new relationships with their environment, effectively reappropriating urban spaces. Lebreton [44] also argues that this “right to the city” is at the heart of parkour. Traceurs might reject property rights, claiming a right of usage. This might create conflict, because of violation of property rights, fear of injury or damage to property, but also because parkour might conflict with different uses of the same spaces [43,45].

However, parkour is not all about transgression. Parkour practitioners have been described as being less anti-authoritarian, and more civil, than skateboarders [12]. There does not seem

to be evidence of vandalism or material destruction of the used spaces [29,46]. And traceurs, like skateboarders, use various non-confrontational strategies to make themselves accepted: “(a) appealing to empathy, leading to gradual (informal) encroachment; (b) formulating positive arguments to gain social recognition and increase their collective presence in the city; and (c) silent reassessment and constant adaptation to avoid conflict.” [47].

II. 4. Parkour environments

People often see parkour as a spectacular exercise that is practiced on rooftops, in a continuous run through the city, jumping over gaps and vaulting over any obstacle. But in reality, practitioners spend most of their time at ground level, rehearsing movements in a spatially limited zone [15,31]. Parkour is usually multi-site: traceurs train in a multitude of “spots”, i.e. places with interesting features for parkour: walls, trees, rails, benches, etc. [43,48]. Parkour is different from most mainstream sports in that it uses non specific structures, rather than functionally designated and separated spaces. Bavinton [9] describes parkour as the reinterpretation of the city as a playground. Traceurs rekindle their inner child, trying to find interesting ways of using the environment rather than the easiest or most obvious ones, trying to develop what they call their “PK vision” [49]. While doing so, traceurs immerse themselves in the city, creating an intimate relationship with their environment [9]. It has recently been shown that traceurs’ observation capacities of the environment can surpass those of gymnasts of similar experience, and are more closely related to the abilities of climbers to read their path [50]. Parkour and climbing are open-skilled sports, which may explain why traceurs and climbers are so good at spotting details in landscapes. On the other hand, practitioners of closed-skilled practices such as gymnastics exhibit lower observation capacities because they do not have to adapt to their environment, which is fixed and standardized.

Traceurs actually create emotional bonds with environments that are usually looked over by most passer-byes [51]. Some “spots” even become pilgrimage sites that are visited internationally, in the same way that street dancing, street art, or riding sports have “sacred” sites. Whether cities preserve them and claim them as part of their patrimony, or ignore them or fight the practice, depends mostly on their politics [52]. Contrastingly, more dedicated structures such as parkour-gyms or parkour-parks have been built recently. This “indoorization” of outdoor sports is a trend that has been observed in other lifestyle outdoor practices, and is

often criticized because it may cause a false sense of security, as well as a loss of the spirit of liberty and of authenticity [19,53].

II. 5. Learning approach

Training in urban environments allows for a form of situated learning, where learning occurs in the same context as the one it will be applied in [31]. One part of parkour is learning and rehearsing a repertoire of movements that have specific names [31]. While parkour seems to be mostly playful, there is also a taste for difficulty and challenge for one's emotional and physical limits [2,48]—or even sometimes a yearning for danger [10]—that goes beyond simple free play. It is a mixture of play and work, freedom and discipline. Unlike in gymnastics or in track and field that are often compared to parkour, rules are flexible, and can be changed easily to progressively add complexity and difficulty. It also allows every practitioner to set their own challenges with their own standards [10,29].

Collective and individual elements are welded together: even when traceurs attempt together the same “challenge”, they leave space for individual interpretation, style and standards [31]. Learning takes place as a process of trial and error more than via verbal instructions [48]. But it is also a collaborative process [31] with limited amounts of traditional coaching [54], where traceurs learn by observation and comparison, mentoring and peer coaching, and frequently give feedback to each other, whether they are veterans or beginners, skilled or less so. Although a large part of social media focuses on the “extreme” aspects of parkour, it sometimes uncovers the process underlying a performance, and it is a breeding ground that offers inspiration for more creativity, tutorials for learning moves, and a community for sharing and meeting each other [49].

III. Life science aspects

While parkour is mostly considered as being intentionally non-competitive, any performance in parkour requires a high level of physical [35,55] and technical [56,57] skills. It will be shown that parkour practice involves accuracy and power regulation to prevent pain and injuries. Moreover, parkour requires adaptation skills as it is commonly practiced in an undedicated environment, on hard ground, and without any special equipment. These particularities lead parkour athletes to develop specific physiques and techniques.

III.1. Physical profile of the traceur

Some body types (height, mass, body shape) are especially well suited to particular sports disciplines [58]. Nevertheless, it is also known that the long-term practice of a sport can shape the neuromuscular system to adapt to the type of performance [59]. A few studies have investigated anthropometric variables in traceurs. First, traceurs have significantly higher body mass as compared to climbers [55]. Indeed, parkour is a very explosive discipline that may induce a shift from slow to fast muscle fibers, and thus explain such an increase of muscular mass, especially on the lower body [55]. Regarding anthropometric profiles, experienced traceurs present a significantly lower ectomorph, higher mesomorph rating than beginners [60] and gymnasts [61]. Mesomorphy defines the body by its stiffness and muscularity, while ectomorphy expresses the thinness of the body [62].

III.2. Performance assessment

The standing long jump (SLJ) is frequently used in sports to assess athletic performance and as an indicator of explosive leg performance. The SLJ is close to the iconic parkour precision jump (Fig. 1) and thus it is a standard test that represents a good starting point to compare traceurs' to other athletes' performances. This comparison has shown that, despite a less controlled and structured training, traceurs could achieve similar or even better performances than other athletes (Table 2) [38,57,62,66,67]. In fact, the average performance of traceurs in SLJ is 248.0 ± 28.1 cm (mean values extrapolated from the studies presented in Table 2), which is comparable or greater than the performance of other high-level athletes (gymnastics SLJ = 251.1 ± 13.5 cm ; various sports SLJ = 223.8 ± 14.9 cm), notwithstanding that the variability is large enough that one should make sure not to draw any definitive conclusion (Table 2). However, if traceurs are more used to horizontal jumps [55], gymnasts' are more accustomed to vertical ones. This would explain that for a similar amount of training, both populations demonstrate similar performances on countermovement jump (CMJ) [35].

Concerning the lower limbs in isometric maximal voluntary contraction (MVC), traceurs achieve 34% greater forces of the knee extensors than a recreationally active group [35], and ~15 to 20% greater plantar flexion [75]. Regarding the upper body, traceurs perform 37.5% better in pull-up exercises and 42.1% in push-up exercises than a recreationally active group [55]. In more distal muscles, traceurs show a 37% greater wrist flexion force than a control group [76], while traceurs exhibit similar grip force compared to the control group [55]. However,

handgrip forces of traceurs are lower than those of trained climbers [77]. Overall, traceurs' muscular strength seems to follow a proximal-to-distal gradient, and muscles seem to be well trained in eccentric mode. Parkour techniques require large amounts of force to propel the body or to absorb high impacts, as it is for leg muscles during high drop landings, which induce the development of high eccentric capacities. As a consequence, the long-term practice of parkour could favor the development of large muscles close to the trunk to maximize the transmission of forces initiated by both lower- and upper-limbs to the whole body.

Article	n	Study population	CMJ (cm)	SLJ (cm)
Parkour				
Leite et al., 2011 [63]	13	>0.5 years of practice	55.9 ± 5.3	253 ± 0.21
Marchetti et al., 2012 [55]	11	3 years of practice, 3 to 5 hours/week	38.9	215.7
Abellán-Aynés & Alacid 2015 [60]	13	5.57±2.34 years of practice	43.1 ± 7.9	277 ± 25
Grosprêtre & Lepers 2016 [35]	15	4.5 ± 0.8 years of practice, 6.4 ± 1.6 hours/week	50.1 ± 4.01	282.7 ± 20.3
Rocha et al., 2018 [64]	24	4 hours/week of practice	37.7 ± 2.9	N/A
Grosprêtre et al., 2017 [65]	7	1 year of practice	29.4 ± 6.9	231.5 ± 22.3
Grosprêtre et al., 2017 [65]	7	5.5 ± 1.6 years of practice, 10 hours/week	36.3 ± 3.2	250.12 ± 29.4
Padulo et al., 2019 [66]	13	3.3 ± 9 years of practice, 7.1 ± 14 hours/week	38.29 ± 6.9	198.3 ± 28.6
Chamorro et al., 2017 [67]	8	1 to 2.9 years of practice	38.9 ± 4.9	232.9 ± 27.3
Chamorro et al., 2017 [67]	4	3 to 4.9 years of practice	37.2 ± 3.1	254.8 ± 26.7
Chamorro et al., 2017 [67]	8	>5 years of practice	47.3 ± 4.9	272.8 ± 12.4
Seyhan et al. 2019 [61]	6	2 years of practice	47.41±6.05	253 ± 61
Gymnastics				
Jensen et al. 2013 [68]	15	elite Danish trampoline athletes	40.1 ± 1.2	N/A
Donti et al. 2014 [69]	10	17.2 ± 4.8 years of practice, 34 hours/week	38.5 ± 0.9	N/A
Karakollukçu et al., 2015 [70]	20	intercollegiate competitive male gymnasts	63.5 ± 1.5	242.4 ± 3.4
Karakollukçu et al., 2015 [70]	20	intercollegiate competitive male gymnasts	58.8 ± 1.6	243.4 ± 3.5
Grosprêtre & Lepers 2016 [35]	15	4.5 ± 0.8 years of practice, 6.4 ± 1.6 hours/week	50.2 ± 5.6	272.9 ± 28.3
Various				
Markovic et al., 2007 [71]	93	soccer, handball, basketball, track and field	47.5 ± 1	237.5 ± 2.5
Porter et al., 2013 [72]	38	football, baseball, basketball, and others.	N/A	207.2 ± 25.9
Becker & Smith 2015 [73]	40	recreationally active undergraduate students	N/A	204.2 ± 26.2
Weakley et al. 2019 [74]	28	semi-professional Rugby union players	N/A	229 ± 23

Table 2. Performances of traceurs and various other athletes in vertical Countermovement Jump (CMJ) and horizontal Standing Long Jump (SLJ).

Performance in parkour is not metric, but very complex to standardize. Rather than developing maximum mechanical power as in track and field disciplines, parkour involves producing the right amount of mechanical power in order to accurately reach the targeted distance [65]. Since tests from other sports are not adapted to fully evaluate the multiplicity of parkour skills, specific tests are starting to be developed, such as sprints with obstacles, repeated [66] or not [78,79], with the performance being evaluated both on time and on the quality of the movements carried out [78].

III.3. Eccentric contraction capacities

Authors have shown that plyometric tests such as explosive push-ups for upper body [55] or drop jumps for lower body [35] better highlight the specificity of traceurs' muscular performances than the usual standardized maximal voluntary contraction test (MVC). Traceurs exhibit stronger knee extensor forces than recreationally active participants, in concentric, isometric and eccentric contractions types. Traceurs results are similar to those of gymnasts and track and field athletes for all contraction modes but eccentric, which is better in traceurs than in other athletes [35]. The particularly high eccentric force of traceurs could be explained by many factors, from the plyometric nature of their training to the frequent practice of drops jumps from large heights.

This importance of eccentric modality in parkour training gives rise to a number of changes in the neuromuscular system, this contraction mode being known to involve a highly specific kind of neural control [80]. Actually, traceurs have shown a particularly low spinal excitability, associated with a high cortical activation [76], which sets them among the most powerful athletes [75].

However, power is not the only parameter that defines parkour practice. It has been suggested that the particular cortical activation patterns of athletes could also come from the extremely wide range of skills traceurs have to manage to constantly adapt to the equally wide range of environmental constraints, such as short or curvy run-ups, diverse heights and width of obstacles, and varying grip quality [76].

Interestingly, it is now accepted that eccentric exercise presents a lower energetic cost than other forms of effort such as concentric exercise [81]. This could indicate that traceurs, mostly performing short duration efforts in this modality, could present weaknesses in the field of endurance performance as compared to other practices. However, parkour training may still help improve cardiorespiratory fitness and aerobic capacities in untrained subjects [82], although it can be argued that for teenagers practicing 1.5 hours of sports per week, any increase in the volume of physical activity would make a difference. It should be highlighted that literature is missing on cardiovascular, metabolic and respiratory capacities of traceurs and thus these results should be interpreted with caution.

III.4. Accuracy constraints

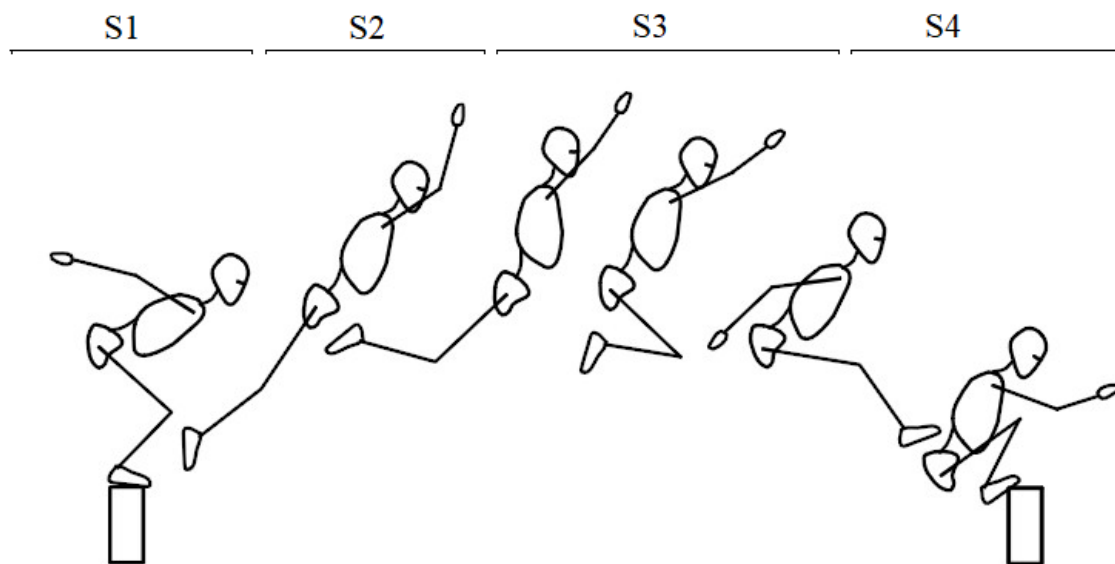


Fig. 1: The precision jump can be broken down into four steps: Counter-movement (S1), Take-off (S2), Flight (S3), Landing (S4).

The most iconic parkour technique is the so-called “precision jump” (Fig. 1). This technique consists in jumping using both feet and arms simultaneously without any run-up, and landing accurately on a target. The landing should be “stuck”, without any step backward or forward nor any wobbling or skidding [83]. This technique is essentially driven by environmental constraints, such as the lack of space to run for gaining velocity, and the small landing area (e.g.

a railing). The movement is similar to the SLJ with an additional constraint on accuracy at landing. The precision jump starts with a counter-movement. From a standing position, athletes perform ankle dorsiflexion together with knee and hip flexion, while swinging their arms backwards [65,84,85] (Fig. 1 S1). The range of motion and speed of the leg and arm joint angles vary depending on the distance, height and precision needed [86]. The lower-limb joint motion leads to the recruitment of leg extensor muscles in a plyometric manner [87].

Then comes the take-off. After storing elastic energy during the counter-movement phase, traceurs perform hip-knee extension followed by ankle plantar flexion to produce the impulse profile that will provide the desired ballistic movement of the center of mass (CoM). At the same time, traceurs perform shoulder flexion so that the arms produce a pendulum movement that transfers angular momentum to the athlete's CoM (Fig. 1. S2) [65,84]. By increasing the take-off speed and rotating the body backwards preparing the posture for landing [65,84], the arm movement improves the jump distance by 21-33% [84,88]. The flight phase follows the take-off (Fig. 1. S3). Although according to Newton's laws of motion, momentum is a conserved quantity during this phase, postural adjustments are still possible without modifying the CoM's trajectory. In fact, instead of stretching out their legs as far as possible prior to landing such as in SLJ, traceurs adapt their posture in flight to stabilize the body and to prepare their landing [89]. This adjustment can be performed either by reaching out far ahead with their feet and swinging their arms back, or on the opposite by keeping their legs under their CoM if they overshot the jump [89]. Shortly before landing, lower-limb muscles co-contract in order to prepare the landing phase strategy [90].

Finally, during the landing phase (Fig. 1. S4), traceurs regulate their CoM trajectory to soften the impact and to avoid collapsing or overstepping. Moreover, traceurs seem to effectively control their stability through dynamic whole-body coordination [56,91,92]. This allows for a compensation of potential miscalculations during earlier phases of the jump. A stiff landing would slow down an excessive speed while a softer landing would allow the CoM to travel farther and catch up any under-impulse. In fact, traceurs have to regulate the stiffness of their legs and especially of their ankles during the landing to cushion high impacts: as a consequence, they land on their forefoot so as to better absorb the impact with a greater ankle dorsiflexion range [89].

Most studies about SLJ focus on the take-off phase while landing is of utmost importance in parkour. Indeed, the goal in parkour jumps is not as much about jumping far as it is about landing precisely and safely; and “sticking” the landing. This power-accuracy trade-off during take-off makes this technique a particularly complex task that has to be well regulated through visual and proprioceptive feedback despite it being an open kinetic chain [93]. This strategy also leads to mechanical regulations during all phases of the jump, from take-off preparation up to landing and stabilization [56,57,65]. When the gap becomes too long for a precision jump and if the configuration allows it, traceurs can gain linear momentum by running: the precision jump becomes a running precision jump (Fig. 2a). In fact, take-off velocity is directly correlated to the jump length according to the ballistic equations [94,95]. This is reminiscent of the track and field long jump but again, with a precision and safety constraint at landing.

In long jump, athletes start their run-up with a preprogrammed acceleration. Then they regulate their running cadence during the last 5 steps to place their foot as close as possible to the take-off board, without overstepping it [88,96]. There is a marked lowering of the CoM during the contact phase of the last stride in order to maximize the vertical impulse [97]. Finally, after a monopodal take-off, athletes balance their posture in the air to counter the clockwise angular momentum acquired during the run-up and the take-off, and thus avoid any excessive forward rotation [98]. Although athletes and traceurs pursue the same goal during the run-up, i.e. reaching optimal velocity and positioning the last foot in the right place, the difference in run-up length and surfaces might induce some differences in the technique. For example, the take-off areas in parkour are not always flat surfaces and they can sometimes be slippery or wobbly (e.g. walls or rails). An error on accuracy could lead to a serious injury. Thus, while for maximal distance it is advised to use hitch-kick or hang style in long-jump [99] (Fig. 2b, 2c), traceurs adopt the stride style to be able to target the landing spot with their foot while in midair (Fig. 2a). The main difference between long jump and running precision jump though, is their landing. Long jumpers land in soft sand and slide from their feet up to their sides. This would result in severe injuries on concrete. Traceurs need to soften the impact to prevent pain and for stabilizing themselves, as it was previously mentioned for the precision jump technique. Further studies are needed to reveal more parkour specificities of the running precision jump.

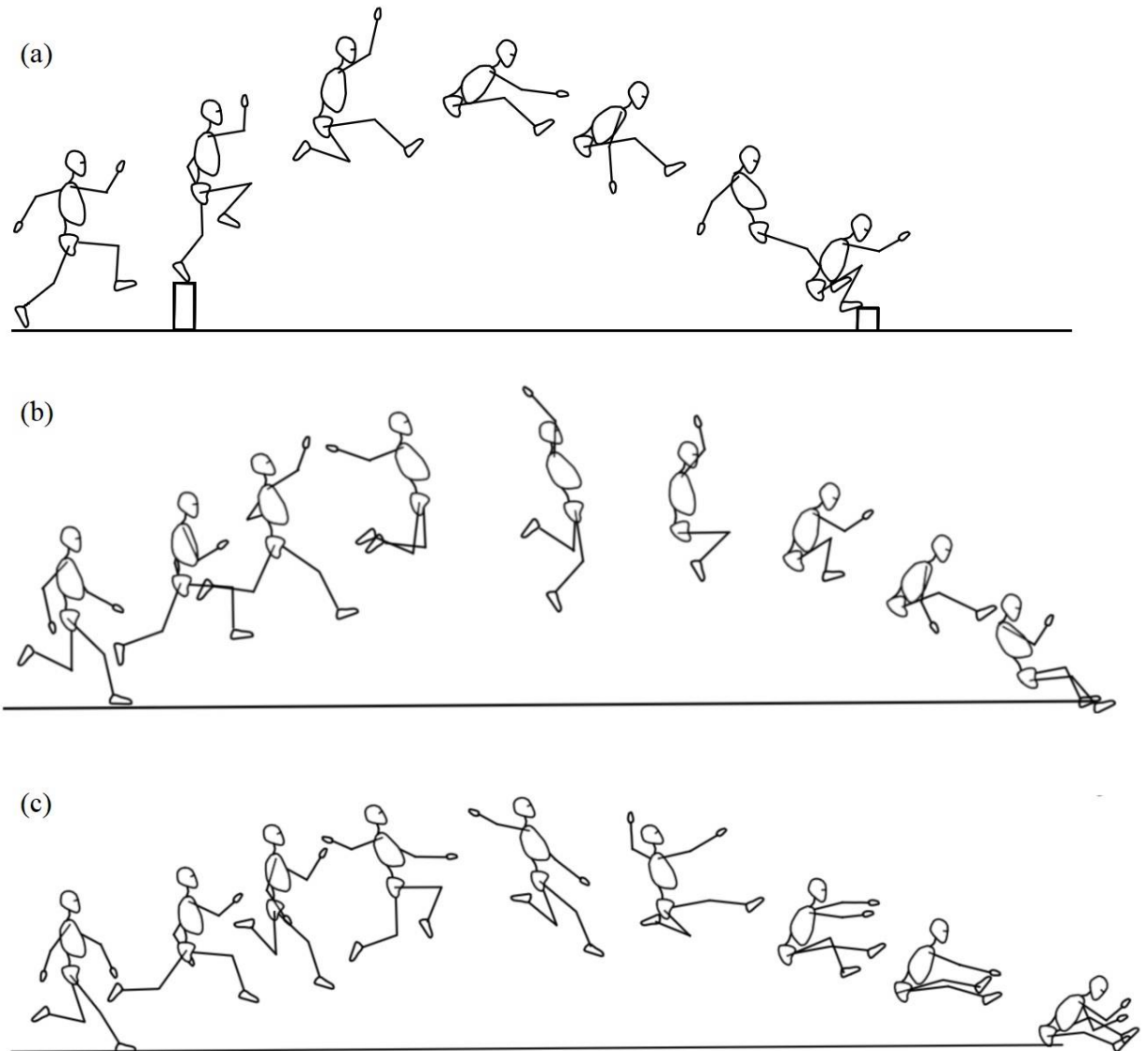


Fig. 2: Three different techniques for the running jump, with or without a precision constraint at landing. (a) Parkour running precision technique, (b) Long jump hang technique, (c) Long jump hitch kick technique

III.5. Parkour and danger

As shown previously, high impacts and unstandardized environments are inherent to the practice of parkour. Parkour practice is not standardized, there is no specific equipment, and traceurs show risk-taking behaviors [26]. As a consequence, one might consider parkour a

dangerous discipline. However, the determinants of parkour pain and injury have not been deeply studied in the scientific literature, and existing studies do not seem to corroborate this hypothesis.

Source	Population	Prevalence of injury (%)	Body localization (%)	Injury type (%)	Injury discriminants	Most frequent injury technique (%)
Da Rocha 2014 [100]	8 W, 73 M (19 +/- 5y)	61.5	lower limbs (57) ankle-foot (29)		min 6 months of practice, other sports practice, earlier fractures	landing
Rosshiem 2017 [101]	3 W, 45 M	NR	lower limbs (29) ankle-foot (19)	fractures (33), wounds (24), ligaments (21), MSD (12)	NR	landing (in ankle-foot injuries)
Maldonado 2017 [102]	85 M	NR	NR	ligaments (53), MSD (17), fracture (15), wounds (15)	NR	landing (41) vaulting (21) arm jump (10) climbing (5) other (23)
Giner-Gran 2020 [103]	7 W, 154 M	70.2	lower limbs (61), ankle-foot (26)	ligaments (55), MSD (15), fracture (6), wounds (12), contusions (21)	min 1 year of practice, no other medical condition	precision jump (41), vaults (22), arm jump (12), climbing (4), other (21)

Table 3: Epidemiological studies related to Parkour. MSD: musculotendinous disorder; NR: not reported

The first papers related to injuries in parkour were single case studies [104–106] reporting mostly fractures at the lower limbs after a bad landing reception in male teenagers. A cross-sectional study was published later by Da Rocha et al. [100], including 91 Brazilian traceurs over a wide variety of ages and experiences (Table 3). The study reported that 61.5% of the participants were injured in the last two years and that 57.1% of the injuries were sustained at the lower limbs. Injured traceurs were significantly older (17.4 vs. 20.4 years old) and had longer training sessions (3.4 h vs. 2.8 h). Three other epidemiological studies were carried out with different methodologies (Table 3). One extracted data from a medical database (n=48) in the USA [101], and the others got direct answers from surveys conducted in France (n=87) [102] and in Spain (n=161). All of them showed that the lower limb, and particularly the foot, was most

prone to injuries. The first study reported mainly fractures, while the two others showed surprisingly close results and counted more ligament injuries. However, people may go less easily to the hospital after a sprain than after a fracture, which could introduce a bias in the study conducted from the medical database.

With so little epidemiological data available in parkour yet, it is difficult to compare it to other sports. Bueno et al.[107] investigated injury prevalence across sports among a statistically representative sample of the Danish population, divided into two groups: 7-15 yo (children), and 15 yo and above (adults). 19.3% of children and 21.5% of adults (mostly males) had been injured within the past 12 months. 100 children practiced parkour (respectively 13 adults), 8 of them were injured (respectively 2 adults) which amounts to 8.8% of overall injury prevalence in parkour (numbers inferred from the data of the article) [108]. In comparison, injury proportion was much lower than in team sports such as handball or soccer (respectively 24% and 23%) and lower than in running (15%). Although we need to be wary of the lack of data, parkour injury prevalence is probably in the same range as in badminton (9.4%), martial arts (8.7%) or gymnastics (7.9%).

Traceurs are often seen as teenagers eager for adrenaline, doing death defying jumps over roof gaps or performing huge harmful drops. As mentioned previously, this idea is often wrong, and that in any case their psychology goes beyond this stereotype [26,37]. Is the risk of injury higher than in other sports? Experience will tell, as parkour is gaining adepts year after year [101] and as epidemiological data explaining the determinants of parkour pain and injury will likely get more comprehensive.

III. 6. Impact dissipation

Once the first preconception that parkour is dangerous is overcome, we end up with another particularity of traceurs: their ability to soften the impact of high drops, sometimes up to 6 m [108]. The capacity to lower impacts has been largely explored in indoor sports and in gymnastics, especially in order to decrease the occurrence of knee injuries. Indeed, most knee injuries are due to a sudden deceleration in the knee during landing [109,110].

Although they both have to “stick” their landings, traceurs and gymnasts manage them in a different way. Gymnasts create higher vertical ground reaction forces than recreational athletes

in the same setting [111]. They land on their forefoot and immediately hit the ground with their heels, and they bend their knees and hips less than recreational athletes [111]. In contrast, traceurs' heels never hit the ground, and they carry on a much deeper squat with great hip, knee and ankle flexions. traceurs have been referred to as landing experts [85] This leads to a different shape of the peak reaction force at landing, with longer duration and reduced intensity [83,89,112] and without any sharp heel strike [102,113]. Moreover, by increasing the landing phase duration and by landing on the ball of their feet, the range of motion of the lower joints can be increased. This allows traceurs to distribute torques along the landing phase duration in order to reduce the associated peak demands and to damp the impact forces to prevent pain and injuries. Another consequence is that the mechanical joint energy increases and extensor muscles have to dissipate large amounts of energy [89]. Interestingly, no study scored parkour landing technique on the Landing Error Scoring System (LESS), which has been proven to be a reliable tool for identifying high risk in biomechanical patterns of landing [114].

When the height becomes significant, traceurs use additional cushioning strategies such as putting their hands at the end of the landing, or initiating a roll to dissipate the remaining energy [108] (Fig. 3). As a comparison, by dropping from the same height, traceurs reduce their landing loading rate from 154.3 to 83.3 BW/s (Body Weight per second) with the forefoot landing and to 64.1 BW/s with the roll landing [83]. These landing strategies are also explored in the context of basketball as they are expected to reduce the risk of landing injury [110].

Several authors have also advised, directly [54] or indirectly [110,115] that elite athletes should learn parkour landing strategies in order to minimize the risk of landing injury. Strafford et al. also specified that for this reason, the use of gym mats in parkour should be prohibited [54]. Indeed, if traceurs get used to mattresses (or begin parkour learning with mattresses), they may adopt poor harmful landing motor patterns and may expose themselves to a higher risk of injury.

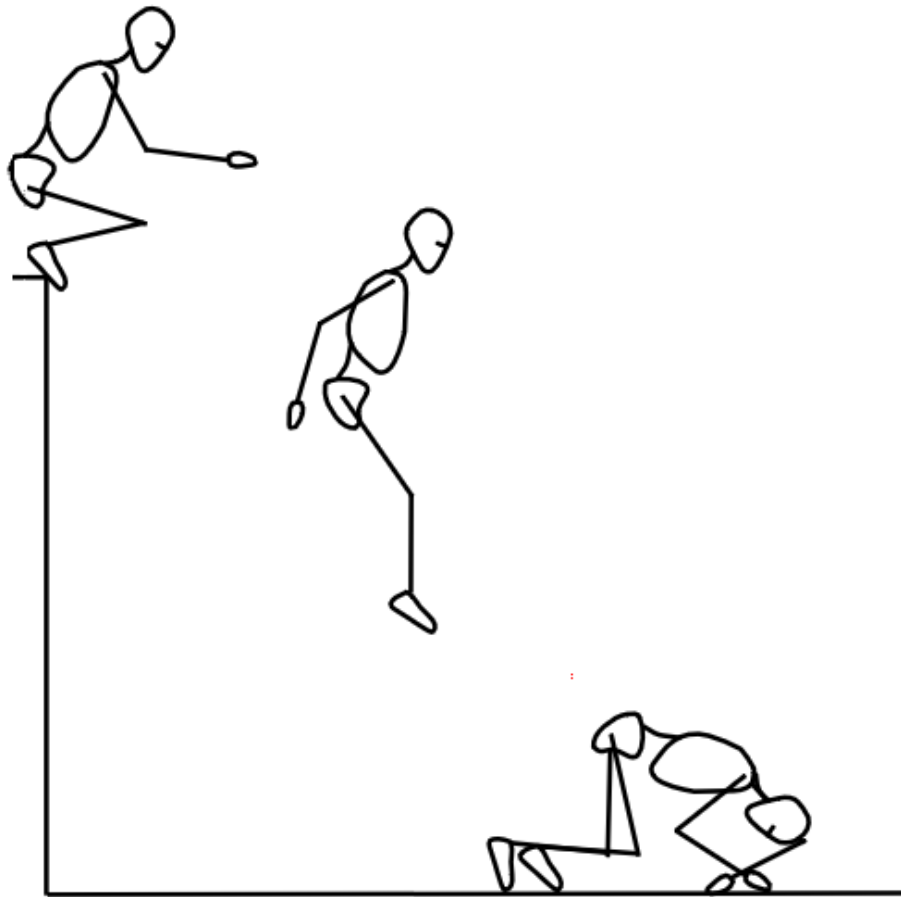


Fig. 3: The most efficient way of dissipating mechanical energy upon landing after a drop jump is to perform a roll.

III.7. Adaptation to the obstacle

So far, it has been demonstrated that parkour performance encompasses trade-offs between power generation and accuracy, and that parkour practice involves learning strategies for dissipating mechanical energy in order to avoid pain and injury. Another skill traceurs have to develop is adaptability. As already pointed out, they appear to have higher cortical activation during sustained maximal contractions as compared to untrained individuals, which can be associated with adaptation skills [75]. In fact, parkour incorporates many other specific techniques that are used by traceurs to overcome a variety of obstacles in a diverse and unstandardized urban environment. These techniques have not been fully explored in the

scientific literature. However, some studies can already provide us with some clues on how these techniques are achieved from a biomechanical perspective.

As an example, consider the wall-pass technique. It consists in running to a wall, putting one or two feet on it to convert kinetic energy into potential energy, and catching the top of the wall (Fig. 4a). The trade-off between the run-up speed and the mechanical work generated by the legs seems to be regulated by traceurs so that the energy transfer is optimal [116].

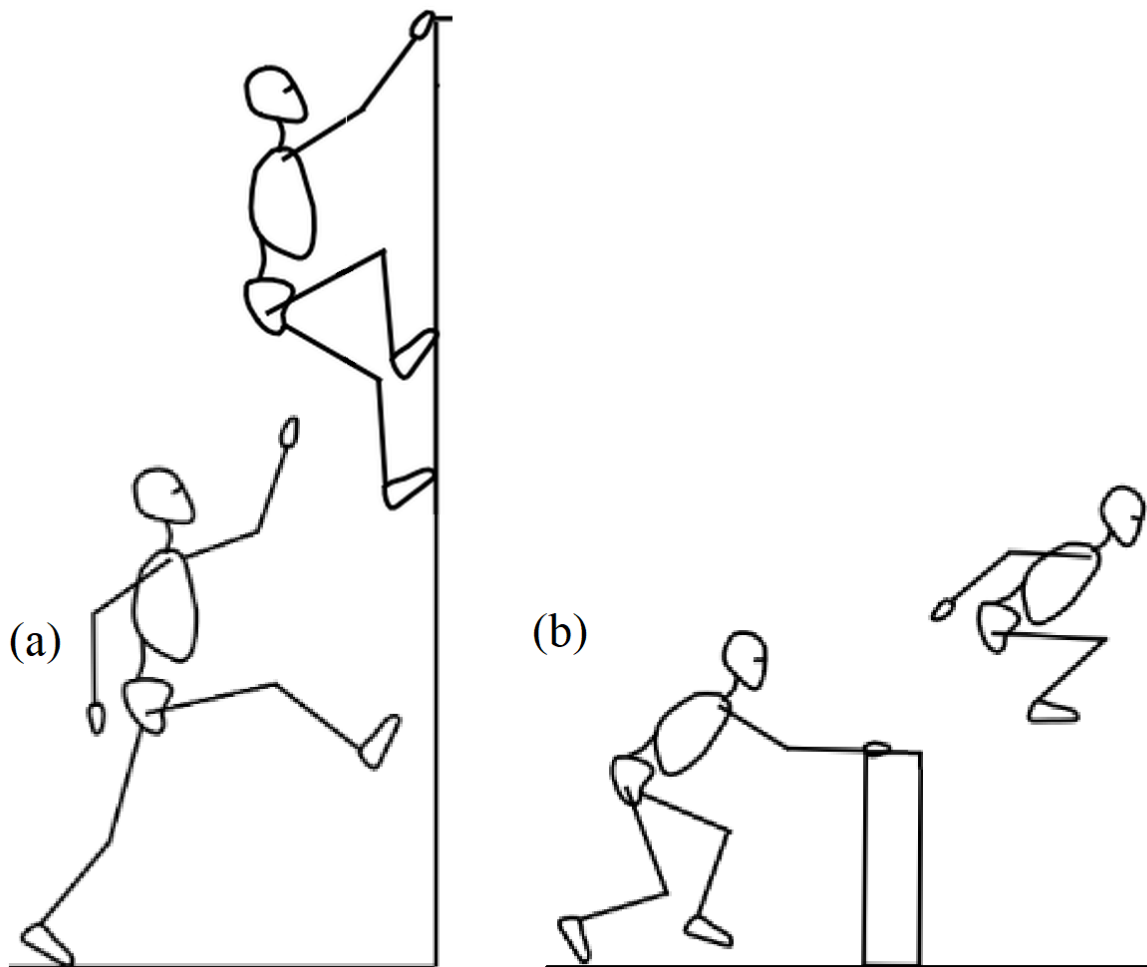


Fig. 4: Apart from landing methods and precision jump, two parkour techniques have been studied: wall-pass (a) and kong vault (b). Wall-pass consists in running towards a wall, stepping up on it, and trying to reach the top. Kong-vault is a fast way to overcome a waist-high obstacle, by using both hands to propel oneself up without slowing down.

Another technique that has been briefly described in the literature is the kong vault technique (Fig. 4b). It is performed by running towards a waist-high obstacle, putting both hands simultaneously on it, and then propelling oneself over the obstacles with knees tucked under the chest in order to pass the obstacle without slowing down. Similarly, this strategy seems to be a trade-off between the run-up speed and the mechanical work generated by the limbs. The first part of the take-off phase serves to propel the body whereas its end contributes to accommodate the body posture for landing. Moreover, the last part seems to be used to accurately adapt the initial velocity and angle of the CoM from the run-up and the initial propulsion [117].

Apart from precision jump, running precision jump, wall pass, and kong jump, other fundamental parkour techniques exist such as safety vault, dash vault, reverse vault, diving kong vault, underbar, as well as lache, tic-tac, cat jump, climb up (Fig. 5). These elementary techniques can also be combined, which results in movements like kong to precision jump, kong to cat leap, double kong vault, etc. None of the above has been studied to our knowledge, and especially not in real-life or in representative conditions. As a consequence, there is still a dearth of scientific research concerning the biomechanics of parkour techniques.

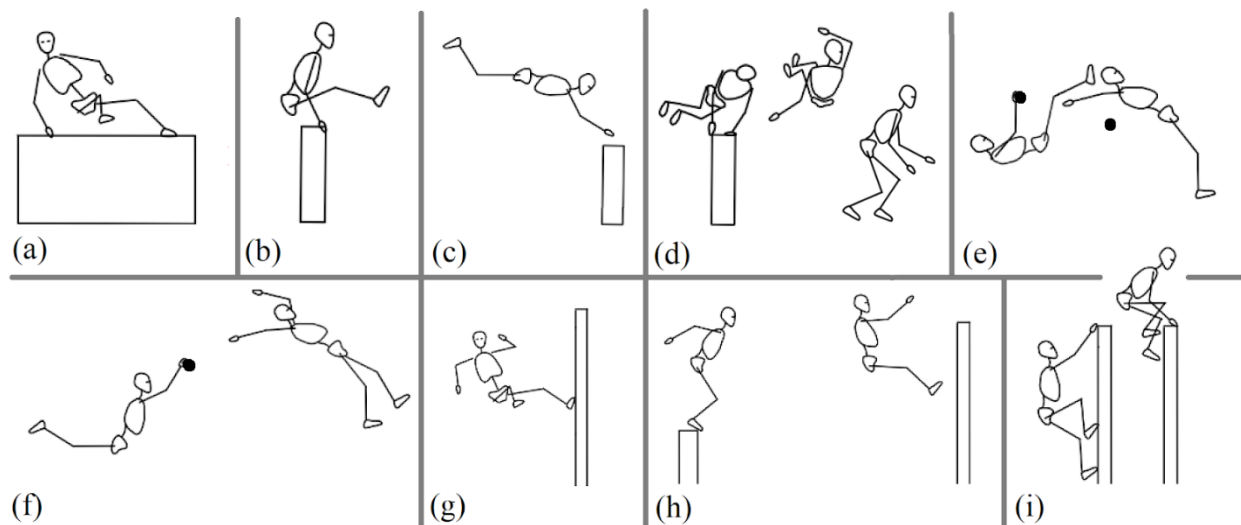


Fig. 5: Other parkour techniques: (a) safety vault, (b) dash vault, (c) reverse vault, (d) diving kong vault, (e) underbar, (f) lache, (g) tic-tac, (h) cat jump, (i) climb-up

Conclusion

This article aimed to characterize parkour and its practitioners. Parkour is a relatively new lifestyle sport in which adaptation skills are crucial to succeed in overcoming diverse obstacles in an efficient and safe fashion. Traceurs seem to have similar muscular performance compared to other traditional sports, which indicates that comparable abilities can be achieved with a different training approach which is less standardized, based on exploring the environment and playing with an infinite variety of exercises. Currently, parkour is mostly non-competitive and its rules are non-written and rather flexible in contrast to other sports. The environment is very often a reappropriated urban space with hard surfaces and different kinds of obstacles. However, parkour practice does not seem to be related to transgression nor to injury risk. More studies are needed to specify the demographics of the discipline. Finally, parkour seems to be a good candidate to captivate young practitioners who are not attracted by traditional sports.

Practitioners have shown to master force regulation so as to be both explosive when long distances have to be covered, and precise at landing. Traceurs have also been found to overcome obstacles with optimal energy management, and to expertly dissipate energy when damping impacts thanks to their eccentric force capacities. However the literature is still limited to very few techniques, and most of the studies have been conducted in less representative environments such as motion capture laboratories. Further studying how these techniques are used by the traceur to adapt to each obstacle situation could help better understand human biomechanics, and such knowledge could be transferred to other sports [54], or to other scientific fields such as robotics [118].

Contributions

Contributed to the “Social Sciences” section: DP and YD.

Contributed to the “Health Sciences” section: SG, GF, DP and GM.

Designed the stick figures: DP

Revised and approved the final manuscript: DP, YD, GF, GM, SG.

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Not applicable.

REFERENCES

1. Belle D, Gros La Faige S. Parkour [Internet]. Intervista. 2009 [cited 2020 Mar 1]. Available from: https://www.librest.com/livres/parkour-david-belle_0-493436_9782357560253.html
2. Angel DJ. Ciné Parkour: A cinematic and theoretical contribution to the understanding of the practice of parkour. North Charleston: CreateSpace Independent Publishing Platform; 2011.
3. Halsey LG, Coward SRL, Crompton RH, Thorpe SKS. Practice makes perfect: Performance optimisation in 'arboreal' parkour athletes illuminates the evolutionary ecology of great ape anatomy. *Journal of Human Evolution*. 2017;103:45–52.
4. Halsey LG, Coward SRL, Thorpe SKS. Bridging the gap: parkour athletes provide new insights into locomotion energetics of arboreal apes. *Biol Lett* [Internet]. 2016 [cited 2020 May 4];12. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5134039/>
5. Hunt NH, Jinn J, Jacobs LF, Full RJ. Acrobatic squirrels learn to leap and land on tree branches without falling. *Science* [Internet]. American Association for the Advancement of Science; 2021 [cited 2021 Sep 3]; Available from: <https://www.science.org/doi/abs/10.1126/science.abe5753>
6. Take Flight®. Fur + Sweatpants (Monkeys vs. Traceurs) | An Original Edit by Dan Chalifoux [Internet]. 2014 [cited 2020 Dec 15]. Available from: <https://www.youtube.com/watch?v=xKk6VEUqhu0>
7. Omar Tamerd. Jackie Chan Parkour Compilation [Internet]. 2018 [cited 2020 Dec 15]. Available from: https://www.youtube.com/watch?v=_95lv1fW8JE
8. Parkour Earth. Parkour Earth issues an Open Letter to member National Gymnastics Federations of the FIG [Internet]. Parkour Earth. 2018 [cited 2020 Dec 15]. Available from: <https://parkour.earth/parkour-earth-issues-an-open-letter-to-member-national-gymnastics-federations-of-the-fig/>
9. Bavinton N. From Obstacle to Opportunity: Parkour, leisure, and the reinterpretation of constraints. *Annals of Leisure Research*. Routledge; 2007;10:391–412.
10. Guss N. Parkour and the Multitude: Politics of a Dangerous Art. *French Cultural Studies*. SAGE Publications Ltd; 2011;22:73–85.

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11. Ameen L, Tani S. Everyday aesthetics in action: Parkour eyes and the beauty of concrete walls. *Emotion, Space and Society*. 2012;5:164–73.
12. Clegg JL, Butryn TM. An existential phenomenological examination of parkour and freerunning. *Qualitative Research in Sport, Exercise and Health*. 2012;4:320.
13. Atkinson M. Parkour, Anarcho-Environmentalism, and Poiesis. *Journal of Sport and Social Issues*. 2009;33:169–94.
14. Gibout C, Lebreton F. Cultures juvéniles et loisirs sportifs de rue : une approche par l'espace public. *Agora débats/jeunesses*. Presses de Sciences Po; 2014;N° 68:71–84.
15. Kidder JL. Parkour: Adventure, Risk, and Safety in the Urban Environment. *Qual Sociol*. 2013;36:231–50.
16. Lamb MD. Misuse of The Monument: The art of parkour and the discursive limits of a disciplinary architecture. *Journal of Urban Cultural Studies*. 2014;1:107–26.
17. Prévitali C, Coignet B, Marchiset GV. Le parkour : approche ethnographique de communautés juvéniles de loisirs dans la ville. *Agora débats/jeunesses*. Presses de Sciences Po; 2014;N° 68:85–97.
18. Rinehart R. Emerging arriving sport: alternatives to formal sports. J Coakley, & E Dunning *Handbook of sports studies* [Internet]. SAGE Publications Ltd; 2000. p. 505–20. Available from: <https://www.doi.org/10.4135/9781848608382.n32>
19. Wheaton B. *Understanding Lifestyle Sport: Consumption, Identity and Difference*. Routledge; 2004.
20. Wheaton B. *The Cultural Politics of Lifestyle Sports*. Routledge; 2013.
21. Suits B. *The Grasshopper: Games, life and utopia*. [Internet]. Toronto: University of Toronto Press; 1978 [cited 2021 Feb 17]. Available from: https://www.goodreads.com/work/best_book/789507-the-grasshopper-games-life-and-utopia
22. Borge S. *What Is Sport? Sport, Ethics and Philosophy*. Routledge; 2020;0:1–23.
23. O'Loughlin A. *A door for creativity – art and competition in parkour*. Theatre, Dance and Performance Training. Routledge; 2012;3:192–8.
24. Gilchrist P, Wheaton B. Lifestyle and adventure sport among youth. In: Green K, Smith A, editors. *Routledge Handbook of Youth Sport*. Oxford, UK: Routledge International Handbooks; 2016. p. 186–200.
25. Hébert G. *L'éducation physique; ou, L'entraînement complet par la méthode naturelle ...* [Internet]. Vuibert; 1912 [cited 2021 Feb 17]. Available from: <http://archive.org/details/leducationphysi00hbgoog>

26. Cazenave N, Michel G. Conduites à risques et variation de l'estime de soi chez les adolescents : l'exemple du parkour. *Annales Médico-psychologiques, revue psychiatrique*. 2008;166:875–81.
27. Serra Gonzales A, Pagnon D, Grosprêtre S, Lemaire S, David M, Gateau A, et al. An educational model for the development of resilience based on Rap and Parkour. 2020. Available from: <https://rapkour.com/wp-content/uploads/2020/07/RAPKOUR-HANDBOOK-EN.pdf?fbclid=IwAR3ExhC1oT2allTqewuUoHklv2IKqzZAJFPkXUXuEANucCa-5f2x8nz8Val>
28. Fernandez-Rio J, Sanz N, Fernandez-Cando J, Santos L. Impact of a sustained Cooperative Learning intervention on student motivation. *Physical Education and Sport Pedagogy*. Routledge; 2017;22:89–105.
29. Gilchrist P, Wheaton B. Lifestyle sport, public policy and youth engagement: examining the emergence of parkour. *International Journal of Sport Policy and Politics*. 2011;3:109–31.
30. Grabowski D, Thomsen SD. Parkour as Health Promotion in Schools: A Qualitative Study on Health Identity. *World Journal of Education*. 2015;5:37.
31. O'Grady A. Tracing the city – parkour training, play and the practice of collaborative learning. *Theatre, Dance and Performance Training*. 2012;3:145–62.
32. Janeckova K, Hamrik Z, Matusova M, Badura P. "I am going out!" – lifestyle sports and physical activity in adolescents. *BMC Public Health*. 2021;21:1079.
33. Stapleton S, Terrio S. Le Parkour: Urban Street Culture and the Commoditization of Male Youth Expression. *International Migration*. 2012;50:18–27.
34. Kidder JL. Parkour, Masculinity, and the City. *Sociology of Sport Journal*. Human Kinetics, Inc.; 2013;30:1–23.
35. Grosprêtre S, Lepers R. Performance characteristics of Parkour practitioners: Who are the traceurs? *Eur J Sport Sci*. 2016;16:526–35.
36. Holzmüller, Philip, Braumüller B. Climb ups or thumbs ups? *German Journal of Exercise and Sport Research* [Internet]. 2020 [cited 2020 Sep 5]; Available from: <https://www.springermedizin.de/climb-ups-or-thumbs-ups/18342262>
37. Merritt CJ, Tharp IJ. Personality, self-efficacy and risk-taking in parkour (free-running). *Psychology of Sport and Exercise*. 2013;14:608–11.
38. Wanke E, Thiel N, Groneberg D, Fischer A. Parkour--"art of movement" and its injury risk. *Parkour - „Kunst der Fortbewegung“ und ihr Verletzungsrisiko*. *Sportverletz Sportschaden*. 2013;27:169–76.
39. European Commission., TNS Opinion & Social. Sport and physical activity: report. [Internet].

LU: Publications Office; 2014 [cited 2021 Feb 17]. Available from:

<https://data.europa.eu/doi/10.2766/73002>

40. Fédération de Parkour, Gateau A, Kleffert E. La pratique féminine du parkour : enquête [Internet]. France; 2020. Available from: https://docs.google.com/presentation/d/1pFCe-rNnuO6HOjYjN6Rhw9dwoP70gKLCySHrrnbulrc/edit?fbclid=IwAR1yrcCI_CErQW10ZXj2HrMjajMp iGjzeF8VZrQhtAehIT_IFTNIb4Ciuxo#slide=id.ga2a873ced5_0_619
41. Wheaton B. Parkour, Gendered Power and the Politics of Identity. In: Thorpe H, Olive R, editors. *Women in Action Sport Cultures*. London, UK: Palgrave Macmillian; 2016.
42. Yochim EC. *Skate Life: Re-Imagining White Masculinity*. fulcrum.org. University of Michigan Press; 2009.
43. Rawlinson CG Mirko. Play in the City, Parkour and Architecture. 2011;19–24.
44. Lebreton F, Routier G, Héas S, Bodin D. Cultures urbaines et activités physiques et sportives. La « sportification » du parkour et du street golf comme médiation culturelle. *Canadian Review of Sociology/Revue canadienne de sociologie*. 2010;47:293–317.
45. Miaux S. Le libre mouvement des corps. Le « parkour », une nouvelle expérience du déplacement dans la ville. *Géographie et cultures*. 2009;99–116.
46. Fuggle S. Discourses of Subversion: The Ethics and Aesthetics of Capoeira and Parkour. *Dance Research*. Edinburgh University Press; 2008;26:204–22.
47. Geertman S, Labbé D, Boudreau J-A, Jacques O. Youth-Driven Tactics of Public Space Appropriation in Hanoi: The Case of Skateboarding and Parkour. *pac aff*. 2016;89:591–611.
48. Larsen SH. What can the parkour craftsmen tell us about bodily expertise and skilled movement? *Sport, Ethics and Philosophy*. Routledge; 2016;10:295–309.
49. Kidder JL. Parkour, The Affective Appropriation of Urban Space, and the Real/Virtual Dialectic. *City & Community*. 2012;11:229–53.
50. Grosprêtre S, Gabriel D. Sport Practice Enhances Athletes' Observation Capacity: Comparing Scenic Change Detection in Open and Closed Sports. *Percept Mot Skills*. 2020;31512520958232.
51. Saville SJ. Playing with fear: parkour and the mobility of emotion. *Social & Cultural Geography*. 2008;9:891–914.
52. Riffaud T. De l'apparition à la disparition : les espaces totémiques des « sports de rue » [Internet]. 2018 [cited 2020 Feb 25]. Available from: https://www.academia.edu/37556435/De_l_apparition_%C3%A0_la_disparition_les_espaces_tot%C3%A9miques_des_sports_de_rue_

DOI: <https://doi.org/10.1007/s40279-022-01642-x>

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53. Bottenburg M van, Salome L. The indoorisation of outdoor sports: an exploration of the rise of lifestyle sports in artificial settings. *Leisure Studies*. Routledge; 2010;29:143–60.
54. Strafford BW, van der Steen P, Davids K, Stone JA. Parkour as a Donor Sport for Athletic Development in Youth Team Sports: Insights Through an Ecological Dynamics Lens. *Sports Med - Open*. 2018;4:21.
55. Marchetti PH, Junior DAL, Soares EG, Silva FH, Uchida MC, Teixeira LFM. Differences in Muscular Performance between Practitioners and Non Practitioners of Parkour. *International Journal of Sports Science*. 2012;6.
56. Maldonado G, Bailly F, Souères P, Watier B. Angular momentum regulation strategies for highly dynamic landing in Parkour. 2017;5.
57. Maldonado G, Bailly F, Souères P, Watier B. On the coordination of highly dynamic human movements: an extension of the Uncontrolled Manifold approach applied to precision jump in parkour. *Sci Rep [Internet]*. 2018 [cited 2020 May 4];8. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6093881/>
58. 1. Santos DA, Dawson JA, Matias CN, Rocha PM, Minderico CS, Allison DB, et al. Reference Values for Body Composition and Anthropometric Measurements in Athletes. *PLOS ONE*. Public Library of Science; 2014;9:e97846.
59. Maffiuletti NA, Martin A, Babault N, Pensini M, Lucas B, Schieppati M. Electrical and mechanical H(max)-to-M(max) ratio in power- and endurance-trained athletes. *J Appl Physiol (1985)*. 2001;90:3–9.
60. Abellan-Aynés O, Alacid F. Anthropometric profile, physical fitness and differences between performance level of Parkour practitioners. *Archivos de Medicina del Deporte*. 2016;33:312–6.
61. Seyhan S. Effects of 8-Week Strength Training on the Vertical Jump Performance of the Traceurs. *JCT*. 2019;8:11.
62. Sheldon WH, Dupertuis CW, McDermott E. *Atlas of Men: A Guide for Somatotyping the Adult Male at All Ages*. Harper; 1954.
63. Leite N, Aguiar Junior RP de, Cieslak F, Ishiyama M, Milano GE, Stefanello JMF. Perfil da aptidão física dos praticantes de Le Parkour. *Revista Brasileira de Medicina do Esporte*. Sociedade Brasileira de Medicina do Exercício e do Esporte; 2011;17:198–201.
64. Rocha JA, Angelo R, Oliveira MP, Szmuchrowski LA, Couto BP, Drummond MM. Chronic effect of strength training on vertical jump performance in parkour practitioners. *SMAES [Internet]*. 2017 [cited 2021 Sep 12];13. Available from: http://smaes.archbudo.com/view/abstracts/issue_id/11932

65. Grosprêtre S, Ufland P, Jecker D. The adaptation to standing long jump distance in parkour is performed by the modulation of specific variables prior and during take-off. *Mov Sport Sci/Sci Mot.* 2017;27–37.
66. Padulo J, Ardigò LP, Bianco M, Cular D, Madic D, Markoski B, et al. Validity and Reliability of a New Specific Parkour Test: Physiological and Performance Responses. *Front Physiol* [Internet]. 2019 [cited 2020 May 4];10. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6831735/>
67. Chamorro MS, Barquero MM, Borbón MR, Ulate FV. Comparación de los componentes de la aptitud física y composición corporal en practicantes de parkour según los años de entrenamiento. *MHSalud: Movimiento Humano y Salud. Universidad Nacional, Costa Rica;* 2017;14:3.
68. Jensen P, Scott S, Krusturup P, Mohr M. Physiological responses and performance in a simulated trampoline gymnastics competition in elite male gymnasts. *Journal of Sports Sciences.* Routledge; 2013;31:1761–9.
69. Donti O, Tsolakis C, Bogdanis GC. Effects of baseline levels of flexibility and vertical jump ability on performance following different volumes of static stretching and potentiating exercises in elite gymnasts. *J Sports Sci Med.* 2014;13:105–13.
70. Karakollukçu M, Aslan CS, Paoli A, Bianco A, Sahin FN. Effects of mini trampoline exercise on male gymnasts' physiological parameters: a pilot study. *J Sports Med Phys Fitness.* 2015;55:730–4.
71. Markovic G. Does plyometric training improve vertical jump height? A meta-analytical review. *Br J Sports Med.* 2007;41:349–55; discussion 355.
72. Porter JM, Anton PM, Wikoff NM, Ostrowski JB. Instructing skilled athletes to focus their attention externally at greater distances enhances jumping performance. *J Strength Cond Res.* 2013;27:2073–8.
73. Becker KA, Smith PJK. Attentional Focus Effects in Standing Long Jump Performance: Influence of a Broad and Narrow Internal Focus. *J Strength Cond Res.* 2015;29:1780–3.
74. Weakley J, Till K, Sampson J, Banyard H, Leduc C, Wilson K, et al. The Effects of Augmented Feedback on Sprint, Jump, and Strength Adaptations in Rugby Union Players After a 4-Week Training Program. *International Journal of Sports Physiology and Performance. Human Kinetics;* 2019;14:1205–11.
75. Grosprêtre S, Gimenez P, Martin A. Neuromuscular and electromechanical properties of ultra-power athletes: the traceurs. *Eur J Appl Physiol.* 2018;118:1361–71.

76. Grosprêtre S, Bouguetoch A, Martin A. Cortical and spinal excitabilities are differently balanced in power athletes. *Eur J Sport Sci.* 2019;1–11.
77. Green J, Stannard S. Active Recovery Strategies and Handgrip Performance in Trained Vs. Untrained Climbers. *Journal of strength and conditioning research / National Strength & Conditioning Association.* 2010;24:494–501.
78. Dvořák M, Baláš J, Martin AJ. The Reliability of Parkour Skills Assessment. *Sports (Basel)* [Internet]. 2018 [cited 2020 May 4];6. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5969187/>
79. Strafford BW, Davids K, North JS, Stone JA. Effects of Functional Movement Skills on Parkour Speed-Run Performance. *European Journal of Sport Science.* Routledge; 2021;0:1–27.
80. Duchateau J, Enoka RM. Neural control of lengthening contractions. *Journal of Experimental Biology.* The Company of Biologists Ltd; 2016;219:197–204.
81. Garnier Y, Lepers R, Assadi H, Paizis C. Cardiorespiratory Changes During Prolonged Downhill Versus Uphill Treadmill Exercise. *Int J Sports Med.* 2020;41:69–74.
82. Dvorak M, Eves N, Bunc V, Balas J. Effects of Parkour Training on Health-Related Physical Fitness in Male Adolescents. *The Open Sports Sciences Journal* [Internet]. 2017 [cited 2020 May 4];10. Available from: <https://opensportssciencesjournal.com/VOLUME/10/PAGE/132/>
83. Puddle DL, Maulder PS. Ground reaction forces and loading rates associated with parkour and traditional drop landing techniques. *J Sports Sci Med.* 2013;12:122–9.
84. Ashby BM, Heegaard JH. Role of arm motion in the standing long jump. *Journal of Biomechanics.* 2002;35:1631–7.
85. Wu W-L, Wu J-H, Lin H-T, Wang G-J. Biomechanical analysis of the standing long jump. *Biomed Eng Appl Basis Commun.* National Taiwan University; 2003;15:186–92.
86. Wakai M, Linthorne NP. Optimum take-off angle in the standing long jump. *Human Movement Science.* 2005;24:81–96.
87. Bosco C, Ito A, Komi PV, Luhtanen P, Rahkila P, Rusko H, et al. Neuromuscular function and mechanical efficiency of human leg extensor muscles during jumping exercises. *Acta Physiol Scand.* 1982;114:543–50.
88. Ashby BM, Delp SL. Optimal control simulations reveal mechanisms by which arm movement improves standing long jump performance. *J Biomech.* 2006;39:1726–34.
89. Maldonado G, Soueres P, Watier B. Strategies of Parkour practitioners for executing soft precision landings. *J Sports Sci.* 2018;36:2551–7.
90. Yeadon MR, King MA, Forrester SE, Caldwell GE, Pain MTG. The need for muscle co-

- contraction prior to a landing. *Journal of Biomechanics*. 2010;43:364–9.
91. Maldonado G, Bitard H, Watier B, Soueres P. Evidence of dynamic postural control performance in parkour landing. *Computer Methods in Biomechanics and Biomedical Engineering*. 2015;18:1994–5.
92. Jabnoun S, Borji R, Sahli S. Postural control of Parkour athletes compared to recreationally active subjects under different sensory manipulations: A pilot study. *Eur J Sport Sci*. 2019;19:461–70.
93. Pagnon D, Martin O. Neuro-mechanical control of the precision jump. ISB [Internet]. 2015 [cited 2020 Mar 1]. p. 540–1. Available from: https://media.isbweb.org/images/conferences/isb-congresses/2015/isb_2015_abstract_book_final.pdf
94. Hay JG. The biomechanics of the triple jump: A review. *Journal of Sports Sciences*. Routledge; 1992;10:343–78.
95. Seyfarth A, Blickhan R, Van Leeuwen JL. Optimum take-off techniques and muscle design for long jump. *J Exp Biol*. 2000;203:741–50.
96. Glize D, Laurent M. Controlling locomotion during the acceleration phase in sprinting and long jumping. *J Sports Sci*. 1997;15:181–9.
97. Lees A, Fowler N, Derby D. A biomechanical analysis of the last stride, touch-down and take-off characteristics of the women's long jump. *J Sports Sci*. 1993;11:303–14.
98. Hay JG. Citius, altius, longius (faster, higher, longer): The biomechanics of jumping for distance. *Journal of Biomechanics*. 1993;26:7–21.
99. Linthorne NP. Biomechanics of the long jump [Internet]. Routledge Handbooks Online; 2008 [cited 2021 Sep 4]. Available from: <https://www.routledgehandbooks.com/doi/10.4324/9780203889688.ch24#>
100. Da Rocha J, Morales JC, Sabino G, Abreu B, Felicio D, Couto B, et al. Prevalence and risk factors of musculoskeletal injuries in parkour. *Science of Martial Arts and Extreme Sport*. 2014;10:39–42.
101. Rossheim ME, Stephenson CJ. Parkour injuries presenting to United States emergency departments, 2009–2015. *The American Journal of Emergency Medicine*. 2017;35:1503–5.
102. Maldonado G. Analysis and generation of highly dynamic motions of anthropomorphic systems: application to parkour. Université Paul Sabatier - Toulouse III; 2017.
103. Giner Gran MÁ. Epidemiology of injuries in parkour and review literature: Epidemiología de las lesiones en el parkour y revisión de la literatura. *SPORT TK-Revista EuroAmericana de Ciencias del Deporte*. 2020;9:85–96.

104. Frumkin K. Bilateral Calcaneal Fractures and “Free Running”: A Dangerously Cool Emerging “Sport.” *Annals of Emergency Medicine*. 9;46:300.
105. McLean CR, Houshian S, Pike J. Paediatric fractures sustained in Parkour (free running). *Injury*. 2006;37:795–7.
106. Miller JR, Demoiny SG. Parkour: a new extreme sport and a case study. *J Foot Ankle Surg*. 2008;47:63–5.
107. Bueno AM, Pilgaard M, Hulme A, Forsberg P, Ramskov D, Damsted C, et al. Injury prevalence across sports: a descriptive analysis on a representative sample of the Danish population. *Inj Epidemiol* [Internet]. 2018 [cited 2020 May 4];5. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5879036/>
108. Croft JL, Bertram JEA. Affordance Boundaries Are Defined by Dynamic Capabilities of Parkour Athletes in Dropping from Various Heights. *Front Psychol* [Internet]. 2017 [cited 2020 Feb 19];8. Available from: <https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01571/full?dom=currents&src=syn>
109. Kay MC, Register-Mihalik JK, Gray AD, Djoko A, Dompier TP, Kerr ZY. The Epidemiology of Severe Injuries Sustained by National Collegiate Athletic Association Student-Athletes, 2009–2010 Through 2014–2015. *J Athl Train*. 2017;52:117–28.
110. Li L, Baur M, Baldwin K, Kuehn T, Zhu Q, Herman D, et al. Falling as a strategy to decrease knee loading during landings: implications for ACL injury prevention. *Journal of Biomechanics*. 2020;109906.
111. McNitt-Gray JL. Kinematics and Impulse Characteristics of Drop Landings from Three Heights. *Journal of Applied Biomechanics*. Human Kinetics, Inc.; 1991;7:201–24.
112. Dai B, Layer JS, Hinshaw TJ, Cook RF, Dufek JS. Kinematic Analyses of Parkour Landings from as High as 2.7 Meters. 2020;13.
113. Standing RJ, Maulder PS. A Comparison of the Habitual Landing Strategies from Differing Drop Heights of Parkour Practitioners (Traceurs) and Recreationally Trained Individuals. *J Sports Sci Med*. 2015;14:723–31.
114. Hanzlíková I, Hébert-Losier K. Is the Landing Error Scoring System Reliable and Valid? A Systematic Review. *Sports Health*. SAGE Publications; 2020;12:181–8.
115. Santello M. Review of motor control mechanisms underlying impact absorption from falls. *Gait Posture*. 2005;21:85–94.
116. Croft JL, Schroeder RT, Bertram JEA. Determinants of optimal leg use strategy: horizontal to vertical transition in the parkour wall climb. *Journal of Experimental Biology* [Internet]. 2019

[cited 2020 Feb 17];222. Available from: <https://jeb.biologists.org/content/222/1/jeb190983>

117. Maldonado G, Bailly F, Souères P, Watier B. Inverse dynamics study of the parkour kong-vault during take-off. *Computer Methods in Biomechanics and Biomedical Engineering*. 2019;22:S331–3.

118. Guizzo E. By leaps and bounds: An exclusive look at how Boston dynamics is redefining robot agility. *IEEE Spectr*. 2019;56:34–9.