Review Article

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 regard to other sports disciplines. Parkour is a lifestyle sport, and as such provides an alternative to mainstream sports, 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 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 landing and to lower limb extremities. This risk is mitigated by 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.

1 Introduction: What is Parkour?

Parkour is a physical activity born in the early 1990s in the suburbs of Paris, France, which 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 have parallels with solo free-climbing, the ability to adapt
Key Points

Parkour is well in line with modern lifestyle sports, which 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.

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 from different academic perspectives, which gives a rather fragmentary understanding of the discipline. This article, which is the first literature review conducted about parkour, aims to characterize the profile of its practitioners (called traceurs) through an extensive multidisciplinary review. ScienceDirect, PubMed, and Google Scholar databases have been screened for the term “parkour,” without a restriction on publication date. Both social science 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 understand the singular position of parkour.

2 Social Science Aspects

Most of the social science 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.

2.1 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 singular 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 other and the environment, and until recently, one of the few points 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,” which 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 nine pioneers who started to develop the activity in the 1990s, 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].

### 2.2 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 world. As a consequence, the demographics of parkour have shifted. According to Gibout and Lebreton [14], parkour tends to attract participants from a lower social class than other urban sports, where participants usually come from middle or upper intellectual classes. However, 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-economic status and participation in parkour practice among school-aged kids in the Czech Republic [32]. The data regarding social class are therefore inconsistent, and further research is therefore 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 the ages of 15–24 years [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 striving for more inclusivity for all, and not embracing 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-woman environments have provided ‘safer’ spaces for entry [41].

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

### 2.3 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-environmental” 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 et al. [44] also argue 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 a violation of property rights, a 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]. Additionally, 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].

### 2.4 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. However,
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,” the discipline’s term for places with interesting features for parkour: walls, trees, rails, and benches. [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. In contrast, 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 overlooked by most passers-by [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]. Contrarily, more dedicated structures such as parkour gyms or parkour parks have been built recently. This “indoorsitization” 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].

2.5 Learning Approach

Training in urban environments allows for a form of situated learning, where learning occurs in the same context as the one in which it will be applied [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 track and field, which 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]. However, 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].

3 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.

3.1 Physical Profile of the Traceur

Some body types (height, mass, and 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 a 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 in 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].
3.2 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 to 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 jumps. This would explain that for a similar amount of training, both populations demonstrate similar performances on the countermovement jump [35].

Concerning the lower limbs in isometric maximal voluntary contraction, traceurs achieve 34% greater force of the knee extensors than a recreationally active group [35], and ~15–20% greater plantar flexion [75]. Regarding the upper body, traceurs perform 37.5% better in pull-up exercises and 42.1% better 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 a 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 is required 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.

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]. As 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 performance being evaluated both on time and on the quality of the movements carried out [78].

3.3 Eccentric Contraction Capacities

Authors have shown that plyometric tests such as explosive push-ups for the upper body [55] or drop jumps for the lower body [35] better highlight the specificity of traceurs’ muscular performances than the usual standardized maximal voluntary contraction test. Traceurs exhibit stronger knee extensor forces than recreationally active participants, in concentric, isometric, and eccentric contraction 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 drop 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

Fig. 1 Precision jump can be broken down into four steps: counter-movement (S1), take-off (S2), flight (S3), and landing (S4)
specific type 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 in order to constantly adapt to the equally wide range of environmental constraints, such as short or curvy run-ups, diverse height 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 with 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 practising 1.5 h 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.

### 3.4 Accuracy Constraints

The most iconic parkour technique is the “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].

| Article | Study Population | CMJ (cm) | SLJ (cm) |
|---------|------------------|---------|---------|
| Parkour | Leite et al. 2011 [63] | > 0.5 years of practice | 55.9 ± 5.3 | 253 ± 0.21 |
| Marchetti et al. 2012 [55] | 3 years of practice, 3–5 h/week | 69±1 | 215.7 |
| Abellán-Aynés and Alacid 2015 [60] | 5.57 ± 2.34 years of practice | 43.1 ± 277 ± 25 |
| Grosprêtre and Lepers 2016 [35] | 4.5 ± 0.8 years of practice, 6.4 ± 1.6 h/week | 50.1 ± 4.01 | 282.7 ± 20.3 |
| Rocha et al. 2018 [64] | 4 h/week of practice | 37.7 ± 2.9 | NR |
| Grosprêtre et al. 2017 [65] | 1 year of practice | 29.4 ± 6.9 | 231.5 ± 22.3 |
| Grosprêtre et al. 2017 [65] | 5.5 ± 1.6 years of practice, 10 h/week | 36.3 ± 3.2 | 250.12 ± 29.4 |
| Padulo et al. 2019 [66] | 3.3 ± 9 years of practice, 7.1 ± 14 h/week | 38.29 ± 6.9 | 198.3 ± 28.6 |
| Chamorro et al. 2017 [67] | 1–2.9 years of practice | 39.8 ± 9.7 | 232.9 ± 27.3 |
| Chamorro et al. 2017 [67] | 3–4.9 years of practice | 37.2 ± 3.1 | 254.8 ± 26.7 |
| Chamorro et al. 2017 [67] | > 5 years of practice | 47.3 ± 4.9 | 272.8 ± 12.4 |
| Seyhan et al. 2019 [61] | 2 years of practice | 47.41 ± 6.05 | 253 ± 61 |
| Gymnastics | Jensen et al. 2013 [68] | Elite Danish trampoline athletes | 40.1 ± 1.2 | NR |
| Doni et al. 2014 [69] | 17.2 ± 4.8 years of practice, 34 h/week | 38.5 ± 0.9 | NR |
| Karakollukçu et al. 2015 [70] | Intercollegiate competitive male gymnasts | 63.5 ± 1.5 | 242.4 ± 3.4 |
| Karakollukçu et al. 2015 [70] | Intercollegiate competitive male gymnasts | 58.8 ± 1.6 | 243.4 ± 3.5 |
| Grosprêtre and Lepers 2016 [35] | 4.5 ± 0.8 years of practice, 6.4 ± 1.6 h/week | 50.2 ± 4.6 | 272.9 ± 28.3 |
| Other sports | Markovic et al. 2007 [71] | Soccer, handball, basketball, track and field | 47.5 ± 1 | 237.5 ± 2.5 |
| Porter et al. 2013 [72] | Football, baseball, basketball, and others | NR | 207.2 ± 25.9 |
| Becker and Smith 2015 [73] | Recreational active undergraduate students | NR | 204.2 ± 26.2 |
| Weakley et al. 2019 [74] | Semi-professional rugby union players | NR | 229 ± 23 |

NR not reported
(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 a 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 athletes 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 in contrast by keeping their legs under their CoM if they overshoot 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 forefeet 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 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 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 five 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 in accuracy could lead to a serious injury. Thus, while for maximal distance it is advised to use a hitch-kick or hang style in long jump [99] (Fig. 2b, c), 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 to stabilize themselves, as was previously mentioned for the precision jump technique. Further studies are needed to reveal more parkour specificities in the running precision jump.

### 3.5 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.

The first papers related to injuries in parkour were single case studies [104–106] reporting mostly fractures of 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 previous
2 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 of age) 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

**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, and c long jump hitch kick technique.

### Table 3 Epidemiological studies related to parkour

| Source                  | Population                  | Prevalence of injury (%) | Body localization (%) | Injury type (%) | Injury discriminants | Most frequent injury technique (%) |
|-------------------------|-----------------------------|--------------------------|-----------------------|----------------|----------------------|-------------------------------------|
| Da Rocha et al. 2014    | 8 W, 73 M (19 ± 5 years)    | 61.5                     | Lower limbs (57)      | Ankle–foot (29) | Minimum 6 months of practice, other sports practice, earlier fractures | Landing                             |
| Rossheim et al. 2017    | 3 W, 45 M NR                | NR                       | Lower limbs (29)      | ankle–foot (19) | NR                   | Landing (in ankle–foot injuries)     |
| Maldonado 2017          | 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         | 7 W, 154 M                  | 70.2                     | Lower limbs (61), ankle–foot (26) | Ligaments (55), MSD (15), fracture (6), wounds (12), contusions (21) | Minimum 1 year of practice, no other medical condition | Precision jump (41), vaults (22), arm jump (12), climbing (4), other (21) |

*M men, MSD musculotendinous disorder, NR not reported, W women*
the others obtained direct answers from surveys conducted in France \((n = 87)\) \cite{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 other studies showed surprisingly close results and counted more ligament injuries. However, people may be more reluctant to go to the hospital after a sprain than after a fracture, which could introduce a bias in the study that extracted data from the medical database \cite{101}.

With so few epidemiological data available in parkour to date, it is difficult to compare it to other sports. Bueno et al. \cite{107} investigated injury prevalence across sports among a statistically representative sample of the Danish population, divided into two groups: age 7–15 years (children), and age 15 years and above (adults). 19.3% of children and 21.5% of adults (mostly male individuals) had been injured within the past 12 months. One hundred children and 13 adults practised parkour, of whom eight children and two adults were injured, which amounts to 8.8% overall injury prevalence in parkour (numbers inferred from the article data) \cite{108}. In comparison, this injury prevalence 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 \cite{26, 37}. Is the risk of injury higher than in other sports? Experience will tell, as parkour is gaining adepts year after year \cite{101} and epidemiological data explaining the determinants of parkour pain and injury will likely become more comprehensive.

### 3.6 Impact Dissipation

Once the first preconception that parkour is dangerous is overcome, we arrive at another particularity of traceurs: their ability to soften the impact of high drops, sometimes up to 6 m \cite{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 \cite{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 \cite{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 \cite{111}. In contrast, traceurs’ heels never hit the ground, and they perform a much deeper squat with great hip, knee, and ankle flexions. Traceurs have been referred to as landing experts \cite{85} This leads to a different shape of the peak reaction force at landing, with a longer duration and reduced intensity \cite{83, 89, 112} and without any sharp heel strike \cite{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 dampen 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 \cite{89}. Interestingly, no study scored the parkour landing technique on the Landing Error Scoring System, which has been proven to be a reliable tool for identifying high risk in biomechanical patterns of landing \cite{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 \cite{108} (Fig. 3). As a comparison, by dropping from the same height, traceurs reduce their landing loading rate from 154.3 to 83.3 body weight units per second with the forefoot landing to 64.1 body weight units per second with the roll landing \cite{83}. These landing strategies are also explored in the context of basketball, as they are expected to reduce the risk of landing injury \cite{110}.

Several authors have also advised, directly \cite{54} or indirectly \cite{110, 115}, that elite athletes should learn parkour landing strategies in order to minimize the risk of landing injuries.
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.

### 3.7 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 with 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 of 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]. 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 obstacle with the 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 accommodating 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 the precision jump, running precision jump, wall pass, and kong jump, other fundamental parkour techniques exist such as the safety vault, dash vault, reverse vault, diving kong vault, underbar, as well as lache, tic-tac, cat jump, and climb up (Fig. 5). These elementary techniques can also be combined, which results in movements such as the kong to precision jump, kong to cat leap, and double kong vault. 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.

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

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 manner. 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 that 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 types of obstacles. However, parkour practice does not seem to be related to transgression or to injury risk. More studies are needed to specify the demographics of the discipline. Finally, parkour seems to be a good candidate for captivating young practitioners who are not attracted by traditional sports.

Practitioners have been 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 dampening impacts secondary 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 studies of 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].

Declarations

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