Attentional focus effects on lower limb muscular strength in athletes: A systematic review

Abstract

Evidence links an athlete's focus of attention to enhancing strength performance. However, additional research is needed to investigate the applicability of studies beyond the tasks and population currently examined. Therefore, we aimed to systematically review studies concerning attentional focus effects on strength characteristics on lower-limb tasks in athletes. Scopus, Web of Science, and EBSCO databases were searched using Prisma PERSIST guidelines and keywords related to the focus of attention, force production processes, and athletes. Participants were categorized: World-class (Tier 5); Elite (Tier 4); Highly trained (Tier 3); Trained/Developmental (Tier 2); Non-athletes (Tiers 1−0); and Mixed (different levels). Fifteen out of 296 studies met the inclusion criteria. Included studies investigated focus of attention effects: on performance (n = 6), between skill levels (n = 2), for learning (n = 5), with respect to participant preference (n = 1), and one study did not state the aim. Studies achieved an average risk of bias score of 'Excellent'; however, findings suffered in the assessment of certainty. Only two studies reported an advantage for one type of attentional focus (external focus) across conditions (g = .13–.42) with Tier 2 and Mixed Tier athletes. Research does not address the needs of elite athletes and there is limited evidence on each type of strength characteristics and muscle action. There is also a need to incorporate methodological steps to promote task-relevant instructions. Research should focus on contextualized information within professional practice to offer stronger translational implications for athletes and coaches.

Key words: EMG; focus of attention; kinetics; muscle action; psychology; strength and conditioning

INTRODUCTION

The link between cognitive and motor processes is empirically established (23, 29, 77). Indeed, for sports practitioners, growing evidence shows that an athlete's focus of attention significantly impacts on performance (8, 72). Accordingly, even for physically-oriented applied practitioners, enhancement through psychological intervention is increasingly expected (31). More specifically, the psychological process of attentional focus has received increasing interest within the strength and conditioning (S&C) domain (19, 65). In this regard, attentional focus research demonstrates that when verbal instructions direct an athlete's attention externally (on the movement effect within the environment) or internally (on bodily movements (99)), this can acutely alter technique, movement and energy efficiency, and performance outcomes (95). For S&C coaches, this is important for improving quality mechanical work when training common and transferable exercises. For example, maximal effort vertical and horizontal jumps (73, 98) where the ground reaction force (GRF) and net impulse production are key performance indicators and relevant to multiple sports skills requiring sprinting and changes of direction. As such, *on what*, *how* and *why* an athlete might apply their focus when learning and performing these types of movements should form part of an S&C coach's professional decision-making process.

Most studies have compared an external (EF; e.g., "focus on pushing the ground") and an internal (IF; e.g., "focus on contracting the leg muscles") focus (102): the former generally produces more efficient and effective movements with better task outcomes (95). Measures that indicate this advantage include lower electromyography (EMG; 56), higher kinematic variability (79), and higher force production when using an EF (61, 87). Mechanistically, an EF is purported to promote automatic, self-organizing motor control processes. In contrast, an IF is said to disrupt the automatic execution, leadings to inefficient motor control. Taken together, this effect is termed the *constrained action hypothesis* (100). However, researchers have mainly investigated the effect of attentional focus within mixed populations (untrained, trained, and athletes (32, 41, 58, 67)) and no systematic review has addressed the effect for competitive athletes, with the analysis of lower body kinetics or EMG measures (54). Accordingly, this may help S&C coaches to optimize their coaching practices.

Despite consistent results, applied research shows high-level athletes to not always use an EF (35, 74, 75). Toner and Moran (85) suggest that 'letting go' of bodily awareness and becoming too automatized can limit the ability to adapt within complex performance contexts. Instead, athletes report a dynamic shift (between an IF and EF) depending on the goal of the task (9, 37, 68). Notably, this dynamic shift of attention may be functional for the preparation and execution of motor skills. For instance, an IF can be equally as beneficial to performance as an EF when the direction is toward a core component of a given action; that is, a key element of the movement that is causative of task execution success (10). Indeed, such a focus could stimulate functional connectivity across brain areas which underpins high level performance (34). Importantly, athletes' attentional focus strategies are not conceptually supported by the dichotomous external–internal paradigm employed in theory-driven research (70). For instance, Collins et al. (28) suggested that different foci are useful, for different tasks, with different athletes, at different skill levels, and (most crucially) for different purposes. From an applied and translational perspective, the methodologies employed in previous studies have been criticized for the following reasons. Firstly, what and where athletes are asked to direct their focus towards have been unfamiliar and/or conflicting with their typical performance state (62). Secondly, instructions have lacked relevance to the skill demands within a sport (81). Thirdly, an imbalance in the lengths of instructions between conditions have led to disproportionate cognitive requirements (16) . Fourthly, the intended timing of the attentional focus has not always been clear or consistent (1, 97) and, finally, those more functional attentional focus instructions for the task have only been described in recent studies (6, 105, 106). Accordingly, assessing the certainty of findings from S&C studies using these applied factors would prove valuable for practitioners when interpreting any overall effect against their intended training goal.

Therefore, this systematic review aimed to, (1) to report methodological design and quality of studies concerning attentional focus effects on strength measured through kinetic variables (e.g., peak force, net impulse, peak torque) and EMG, and the muscular strength mechanisms involved during lower-limb exercise tasks in athletes; (2) report the effect of different attentional foci on strength measures and/or outcomes; (3) provide an assessment of certainty evaluation pertaining to findings using methodological criticisms from contemporary literature. Notably, this final objective aligns with recent guidelines for conducting systematic reviews for applied purposes (16).

METHODS

Experimental Approach to the Problem

The current systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines (71) and PERSIST (Prisma in Exercise, Rehabilitation, Sport medicine and Sports science) 2021 guidance (2). Consultation with PROSPERO indicated that the review did not need to be pre-registered because no clinical health-related outcomes were measured.

Eligibility Criteria

The search and selection of articles was based on the Participant, Intervention, Comparator, Outcome, Study design (PICOS) strategy. The target *population* was: (i) adolescents and adults aged over 16 years old (from circa-peak or post peak height velocity); (ii) competitive athletes (not involved at academy level) of defined training levels (i.e., local, national, international, world class; (64)); (iii) without injury or disability. The *intervention* could be acute or longitudinal (i.e., > 8 weeks) in nature but needed to involve lower limb strength exercise tasks. Articles were excluded if they (i) involved technical skills such as kicking, jump roping, cycling, balance, or postural control; (ii) compared inter-limb asymmetry; (iii) focused on physiological parameters (e.g., oxygen consumption). *Comparator* required methodological procedures comparing different forms of attentional focus and were purposefully defined in the research methodology. *Outcome* measures included kinetics or EMG data. *Study design* included both randomized controlled trials (RCT) and crossover designs. Finally, non-original (i.e., editorials, letters, reviews, or conference abstracts), non-peer reviewed, and non-English written sources were excluded.

Information Sources and Search Strategy

A systematic search was conducted in December 2022 and updated in August 2023 using three databases: Scopus, Web of Science (Web of Science Core Collection 253, MEDLINE, BIOSIS Citation Index, KCI-Korean Journal Database, Derwent Innovations Index, Russian Science Citation Index, SciELO Citation Index), and EBSCO (Medline, E-Journals, APA PsycInfo, Psychology and Behavioral Sciences Collection, APA PsycArticles). Articles were searched for using a three-level strategy (online appendix, Table S1). Reference lists of relevant identified studies were also screened for additional articles not detected by the systematic search.

Selection Process

Results from the three electronic databases and additional screening method were imported to EndNote web (Clarivate, USA) for processing. Prior to article screening, duplicates were removed from the exported batch files from the databases. At this point, irrelevant articles were removed by the first author (DP) based on the title and abstract. Following, two authors (DP and MB1) independently screened the title and abstract of each article. Based on the information gained from the study title and abstract, articles were categorized in three groups: "eligible", "not eligible", or "to check" according to the pre-specified eligibility criteria. If a study appeared to meet eligibility criteria, or if the relevance of the study was uncertain, the full text was retrieved. The same two authors independently reviewed the full texts and checked for inclusion agreement. When there was a disagreement (< 5%) a third reviewer (MB2) was consulted with a discussion between all three reviewers until a consensus was reached (80).

Data Collection Process

Participants within each eligible study were categorized according to the classification framework defined by McKay et al. (64), to signify their training and competitive status by specific tiers: *World class* (Tier 5; e.g., top 10 at an Olympics/World Championships, maximal or nearly maximal training, exceptional skill-level achieved); *Elite and competing at international level* (Tier 4; e.g., maximal or nearly maximal training, highly proficient in skills required to perform sport); *Highly trained and competing at national level* (Tier 3; e.g., completing structured and periodized training, developing proficiency in skills required to perform sport); *Trained/developmental and competing at local level* (Tier 2; e.g., regularly training ~3 times per week and limited skill development) and *mixed* (comparing different levels; Mixed category). Studies meeting all inclusion criteria but assessing exclusively recreationally active population in a non-competitive context (Tier 1) were categorized as "not eligible: students and general population". This categorization enabled a ratio to be calculated for the two participant groups (i.e., athletes : non-athletes). Corresponding authors were contacted by e-mail in cases of missing or unclear data (n = 8).

Ballistic strength tasks were categorized based on the mechanisms of muscular action involved. Drop jump was classified as influenced by fast *stretch shortening cycle* (SSC) mechanisms with ground contact time (GCT) < 250ms (86); regarding CMJ, there are several processes that could influence the activation and the contribution of fast or slow SSC. For this reason CMJ was categorized as pre-stretch mechanisms. Furthermore, sprint acceleration was classified as muscle action with *pretension* mechanisms, as muscles have to develop pretension before initial ground contact (88).

Outcome measures were grouped into three categories: EMG-derived measures; Kinetics, force-time variables recorded with a force platform, such as peak GRF and net impulse, or recorded with an isokinetic machine, such as peak torque; Performance, indirect measures calculated starting from kinetics outcomes, such as jump height (JH) or reactive strength index (RSI).

For the studies using Cohen's d effect sizes (ES), Hedges' g was calculated by an equation (52) to examine and compare the extent of the focus of attention effects. This approach enabled the estimation of unbiased effects and standardized comparisons between protocols. ES was interpreted as trivial (< 0.2), small (0.2–0.5), medium (0.5–0.8), or large (> 0.8).

Data Extraction

Since the studies within this review were largely heterogeneous in nature when considering differences across tasks, participants, instructions, and outcomes (e.g., EMG, kinetic measures), meta-analysis was not deemed appropriate nor useful for the aim of this study. Instead, data were synthesized and presented in both a tabular and narrative format using the following study characteristics: (i) study design (RCT, cross-over); (ii) study aims; (iii) participant characteristics (training status, age, sex, sport, and country); (iv) strength task (task, task experience, movement execution, and muscle action mechanisms); (v) attentional focus (nature, experience, and timing); (vi) outcomes (kinetics or EMG data), and; (vii) all findings reported according to each study's design (i.e., *p* value and Hedge's *g* ES for pre vs. post and/or retention). Findings without coherent results across conditions were classified as "inconsistent" between tasks or measures.

Finally, in meeting the recognized need suggested by Bobrownicki et al. (15) for systematic reviews of interventions to specifically address key and known issues within the topical literature, (viii) identification of applied methodological concerns highlighted by others that can be considered a level of evaluating the "certainty" of findings. Given the sensitive evaluation of this latter item, methodologies were reviewed by an additional applied researcher (HJC) and discussed to achieve a consensus on missing/problematic features. Notably, this evaluation was informed by a pragmatic philosophy designed to impact on applied practice through the following study design components: the presence of manipulation checks, balance of instruction length across groups, individualization of foci, quality of reported justification or relevance of instructed foci for the task (16, 17, 28) Extracted information were inserted into tabular format for ease of comparison.

Methodological Quality Assessment

Conventionally, when evaluating the methodological quality of studies, one of the following assessment scales is used: the “PEDro”, “Delphi scale” or the “Cochrane scale”. However, non-healthcare studies, such as strength and conditioning, tend to be scored low on these scales due to inappropriate scale criteria. Therefore, this systematic review adopted the alternative evaluation criteria introduced by Brughelli et al. (20), which utilizes the most relevant scores from the three aforementioned scales. The scale utilizes 10-items ranging from 0–20 points (online appendix, Table S2) with the score for each criterion reported as follows: 0 = clearly no; 1 = maybe; and 2 = clearly yes. Based on the total quality score, three classes of methodological quality were identified: low (≤ 50% of total points); good (51–75% of total points); and excellent (>76% of total points). Two authors (DP and MB1) independently performed the assessment, and a consensus process was in place in the instance of a disagreement arising (0% of articles).

RESULTS

A full breakdown of the article selection strategy and result as depicted in the PRISMA 2020 flow diagram are shown in Figure 1. The search identified 511 potential records, with 299 remaining after removing duplicates (*n* = 211). Another 226 studies were manually excluded following title and abstract screening, and 73 studies were assessed for eligibility. Seven articles were identified from the reference lists of identified studies from the database searches. Thirty-eight studies did not include competitive athletes and therefore were included in the category “not eligible”: students and general population. Following the search and review strategy outlined above, 15 articles were identified as eligible for review having met all inclusion criteria.

*****Figure 1 here*****

Figure 1. PRISMA flow chart of data extraction from the literature search

Study Characteristic

Descriptive data for the 15 identified studies can be found in Table 1, with summary findings presented in the subsections below.

*****Table 1 here*****

Study Designs

Study designs were mixed. Six studies employed RCT (7, 39, 53, 57, 92, 93), within which two were longitudinal in nature (39, 57) and four were acute (7, 53, 92, 93). Nine studies used a within-subject crossover design (11, 30, 38, 43, 44, 49, 51, 60, 94), one of which were not counterbalanced (43). Longitudinal studies (*n* = 2 (39, 57)) lasted eight and nine weeks, whereas acute studies ranged from same day testing (*n* = 7 (11, 30, 38, 49, 53, 60, 94)) to testing over 3 days (*n* = 2 (44, 51)). Four acute studies did not report the duration of the testing period (7, 43, 92, 93). Four of acute studies tested for retention effects (53, 92, 93).

Declared Study Aims

The study aims across eligible articles were generally similar but with some variation. The most common study aim was to assess the difference in performance between different focus of attention conditions (*n* = 6 (30, 38, 43, 44, 53, 94)). A small number of studies replicated this aim but compared the effects: between experienced and inexperienced athletes (*n* = 2 (38, 94)), in a learning context (*n* = 2 (7, 53)), on retention (*n* = 2 (92, 93)), during transfer between different motor tasks (*n* = 1 (7)) and, finally, in consideration of participant preference (*n* = 1 (43)). Despite implementing a methodology to compare the effect of three different attentional foci, one study meeting all eligibility criteria did not state this in their aim, instead, the authors focused on manipulating the ratio of forces during an acceleration task and identifying how this affected performance and associated process measures (11).

Participant Characteristics

Most studies were conducted using participants with Tier 2 status (*n* = 8 (7, 30, 43, 53, 57, 60, 92, 93)), followed by Tier 3 status (*n* = 4 (11, 38, 39, 51)), mixed level of Tier 2 and 3 status (*n* = 2 (44, 94)), and Tier 4 status (*n* = 1 (49)). No studies used the highest Tier 5 level of participant status. Forty-one studies initially selected for eligibility were excluded because the participants were classified as tier 1, i.e. 'recreationally active individuals who achieve the physical activity standards and may participate in a variety of sports activities without a specific commitment or focus on competition'. Sports included individual and team sports, with 14 studies combining participants from multiple sports into one sample and one study using participants from only single sports, namely, track sprinters (94).

The majority of participants were male (*n* = 440; female, *n* = 96) and were aged between 19–28 years (M_{age} = 24.75 years). Studies were conducted globally and where it was either stated in the methodology section or there was a single affiliation for authors, we can reasonably report that participants were recruited from the following geographic locations: USA (*n* = 3 (49, 51, 94)), Netherlands (*n* = 3 (7, 92, 93)), Australia (*n* = 2 (43, 44)), Iran (*n* = 2 (39, 53)), UK (*n* = 2 (11, 60)), Japan (*n* = 1 (38)), and Ireland (*n* = 1 (30)). One study did not report the nationality of the participants and this could not be assumed based on multiple author affiliations (57).

Characteristics of the Strength Tasks

Athletes in the acute studies performed mainly single ballistic movement tasks (i.e., those that accelerate throughout the entire concentric phase of the movement) such as a vertical drop jump (DJ) influenced by fast SSC (*n* = 5 (7, 30, 38, 92, 93)); countermovement jump (CMJ) involving pre-stretch mechanisms (*n* = 3 (43, 49, 53)) and 10 m linear running acceleration involving pretension mechanisms (*n* = 3 (11, 51, 94)). Other non-ballistic strength tasks used were isokinetic machine single joint testing (*n* = 1 (60)) and isometric mid-thigh pull (IMTP; *n* = 1 (44)). Longitudinal studies similarly used DJ and CMJ (*n* = 1 (57)) and the DJ plus isokinetic machine single joint testing (*n* = 1

(39)). Most of the studies investigated double leg squatting pattern in the vertical direction (*n* = 10 (7, 30, 38, 43, 44, 49, 53, 57, 92, 93)), followed by pooled horizontal movements (*n* = 3 (11, 51, 94)), and lastly single leg pattern (*n* = 2 (39, 60)). Single task with non-ballistic movements involved isometric (*n* = 1 (44)) and isokinetic (*n* = 1 (60)) muscle actions. Finally, multiple task studies with longitudinal interventions tested both jumps influenced by fast SSC and pre-stretch mechanisms (*n* = 1 (57)) and isokinetic and fast SSC (*n* = 1 (39)). Results are shown in Table 2

The task experience was heterogeneous: some studies defined the participants as experts (*n* = 1 (49)), experienced (*n* = 2 (53, 57)), not experienced (*n* = 2 (39, 44)), familiar (*n* = 2 (51, 60)) and intermediary experience (*n* = 1 (30)) with the task; a few studies compared groups with different levels of experience: expert versus not expert (*n* = 1 (94)), experienced versus not experienced (*n* = 1 (38)). One third of studies did not provide information regarding the participants' task experience (*n* = 5 (7, 11, 43, 92, 93)).

*****Table 2 here*****

Outcomes

Based on the selected criteria, studies analyzed multiple (*n* = 11 (11, 30, 38, 39, 43, 49, 51, 53, 57, 60, 94)) or single (*n* = 4 (7, 44, 92, 93)) outcomes. Most studies measured only kinetics outcomes while two combined kinetics with EMG (*n* = 2 (51, 60)) through force platforms, isokinetic machine, and bi-polar surface electrode instruments. Among the studies adopting ballistic tasks, the outcomes analyzed were: peak vertical force (*n* = 7 (11, 30, 39, 43, 44, 49, 53)), jump height (*n* = 6 (30, 38, 43, 49, 57, 92)), average force and mean concentric force (*n* = 4 (11, 43, 49, 57)), contact time (*n* = 3 (30, 38, 57)), average horizontal force (*n* = 2 (11, 94)), concentric and propulsive impulse (*n* = 2 (11, 49)), leg stiffness (K_{vert}; *n* = 2 (30, 38)), peak velocity (*n* = 2 (43, 49)), reactive strength index (*n* = 2 (30, 38)), resultant force (*n* = 1 (11)), time to peak force (*n* = 1 (51)), eccentric peak force (*n* = 1 (53)) mean eccentric rate of force development, peak and mean power (*n* = 1 (49)), displacement (*n* = 1 (53)), and mean EMG activity of the vastus lateralis (VL_{EMG}) and medial gastrocnemius muscles (GM_{EMG}; *n* = 1 (51)). Two studies showed vertical GRF measures (N/kg) without explaining if the data referred to mean or peak value (7, 93). The studies using non-ballistic tasks analyzed peak vertical force (*n* = 1 (44)), hip abduction and external rotation torque (*n* = 1 (39)), and lastly, peak knee extension, average power, mean muscle activity of VL_{EMG}, vastus medialis oblique (VMO_{EMG}), rectus femoris (RF_{EMG}) muscles, and the $VMO{:}VL_{EMG}$ activation ratio (*n* = 1 (60)).

Findings and Effect Sizes for Significant Differences

All findings are reported in the next sections according to each study design. For those studies indicating partial eta squared (η_p^2) ESs (*n* = 3 (30, 51, 60)), it was not possible to calculate Hedges' *g* ESs.

Consistency of Experimental Effects

Within each study there were multiple or single outcomes (dependent variables) employed relating to strength. When comparing experimental (i.e., EF and IF) and control conditions within studies, it was expected that there would be a significant interaction between these measures and condition (independent variable). However, it was not the case that *all* dependent variables showed a significant difference, nor they were universally consistent across conditions. For example, the control condition outscored one or both of the experimental conditions on *some* outcomes. Results are shown in Table 3.

Two studies showed benefit of an EF (*g* = .13–.42) when performing CMJ and IMTP tasks with Tier 2 and Mixed Tier athletes (44, 53). Inconsistent results were found across outcomes for the same task (*n* = 3; *g* = .14–.69 (11, 30, 51)), between different tasks (*n* = 2; *g* = .57–1.45 (39, 57)), and the same outcome and task (*n* = 1; no ES available (93)). The inconsistent studies utilized CMJ, DJ, running acceleration, and isokinetic abduction tasks with Tier 3 (*n* = 3 (11, 39, 51)) and Tier 2 (*n* = 3

(30, 57, 93)) athletes. Regarding the inconsistent studies with Tier 3 athletes, an EF had a larger impact than neutral focus (NF) and IF on peak hip abduction torques in an isokinetic task (*g* = .57), but no difference was found for a single leg landing task in a study consisting of multiple tasks (39). A NF had a larger impact on outcome measures than an EF (*g* = .45) and IF (*g* = .59) when manipulating the ratio of force applied during an acceleration task (11). Contrary to this finding, however, for other outcomes an IF had significant benefit over EF and NF on peak vertical force (IF vs. EF; *g* = .28; IF vs. NF, *g* = .57) and vertical impulse (IF vs. EF *g* =.17; IF vs. NF *g* = .65). Lastly, no significant difference was found across conditions in the time to peak force and GM_{EMG}, but an IF showed higher mean EMG activities in rear foot VL (*g* not calculable; no difference between EF and NF) and front leg VL across conditions (*g* not calculable) when compared to EF (51).

Studies with inconsistent results in Tier 2 analyzed jump tasks. One study found no difference across conditions in contact time and JH measures (30). On the other hand, an EF had a more significant impact than IF and NF in the RSI, and an EF showed superior effects when compared to a NF on relative and peak GRF and K_{vert} (ES not calculable) in a DJ task. Another study showed inconsistent results across participants for peak GRF (ES not available (93)). Lastly, in one study analyzing multiple tasks (57), the EF group showed significantly greater enhancement than both IF and NF groups in the JH (*g* =1.16) and mean GRF (*g* = 1.45) in CMJ task. Conversely a NF in this study showed significantly shorter contact time compared to EF and IF (*g* = .9) and JH compared to IF (*g* = 1); in turn, EF improved mean GRF compared to an IF and NF (*g* = 1.16).

One study showed results based on the task experience (non-expert, EF: *g* = .26–.44; expert, NF: *g* = .27–.56) on a DJ task with Tier 3 athletes (38). In studies without a control/NF condition, it was shown in one study that the effect of EF instructions on strength was larger than with IF regarding CMJ measures (Tier 4; *g* = .32–.75 (49)), and in another study no difference between an EF and IF on the level of force produced was found (Tier 2; (60)). However, the IF generated higher EMG activation than with an EF in an isokinetic knee extension task (*g* = not calculable). Finally, studies with no effect on outcomes across conditions (*n* = 4; *g* = .12–.18; *p* > .05) involved CMJ, DJ, and running acceleration tasks with mixed Tier (*n* = 1 (94)) and Tier 2 (*n* = 3 (7, 43, 92)) athletes.

*****Table 3 here*****

Attentional Focus: Nature, Experience, and Timing

The reviewed studies compared the impact on performance when adopting an IF or EF (*n* = 2 (49, 60)), with the majority of studies also comparing these effects to different control conditions consisting of a NF (*n* = 6 (30, 38, 43, 44, 53, 94)), no instruction (*n* = 6 (11, 39, 51, 57, 92, 93)), or with a non-specified focus of attention (*n* = 1 (7)).

Within focus of attention conditions, EF instructions directed participants' focus to the ground or reaching a high point (*n* = 12 (7, 11, 30, 38, 43, 44, 49, 53, 57, 92-94)) during jumps and acceleration running tasks, and similarly pushing against a pad during an isokinetic task (*n* = 1 (60)). IF instructions were related to the movement or feeling of bodily processes such as extending lower limb joints (*n* = 11 (7, 11, 30, 38, 39, 49, 51, 57, 92-94)), reaching with the fingers (*n* = 1 (53)), or focusing on the muscular sensation (*n* = 3 (43, 44, 60)). In studies that employed a NF, most of instructions were related to performing to the best of participants ability (*n* = 3 (30, 38, 94)). For example, Furuhashi et al. (38) used "Step off the box, land on the balls of your feet, and after landing fully and explosively extend your ankles, knees, and hips as rapidly as possible to jump high" for IF and "Step off the box, jump fast, imagine the ground is a hot surface, get off the ground as quickly as possible, imagine you are like a stiff spring, and focus on jumping to the roof" for EF. Halperin et al. (43) used "Attempt to jump as high as you can while focusing on contracting your leg muscles as hard and as fast as you can" for IF and "Attempt to jump as high as you can while focusing on pushing of the ground as hard and as fast as you can" during a jump tasks. None of the studies reported the experience/familiarity of the participants in previously using the required attentional focus instructions.

Timing of instructions varied based on the number of trials: for fewer trials, the instructions were provided before every execution (*n* = 6 (30, 38, 39, 44, 51, 94)), while for more trials they were provided at regular intervals during the trials (*n* = 4 (7, 39, 92, 93)), with the frequency differing. Longitudinal studies did not administer any attentional focus instructions when assessing for skill transfer following the intervention period (39, 57). Six studies (11, 43, 49, 53, 57, 60)) did not report the timing of attentional focus instructions. No study specified when exactly the focus of attention should be implemented by the athletes (i.e., immediately before they perform the task or whilst performing the task).

Quality Assessment

Table 4 shows the individual scores for the quality assessment. Values ranged from 13–20 points (good to excellent), with an average score of 16 points (excellent). Regarding the individual quality assessment, nine studies were categorized as excellent (11, 30, 38, 39, 43, 53, 57, 92, 93), while the remaining studies were categorized as being of good quality.

*****Table 4 here*****

Certainty of Findings

As per the criticisms identified within the literature to date, the review identified several translational limitations pertaining to the study designs. Notably, only a small number of studies (*n* = 2 (11, 49)) reported any manipulation check to assess the type of attentional focus used by participants during the tasks. Six studies (11, 39, 51, 57, 92, 93) did not utilize focus of attention instructions for the NF or control condition (CTRL), and three studies were not balanced for word length between NF, IF, and EF (7, 92, 93). As an example of such an imbalance, one study used “Attempt to jump as high as you can” for the NF, “Attempt to jump as high as you can while focusing on contracting your leg muscles as hard and as fast as you can" for the IF, and "Attempt to jump as high as you can while focusing on pushing of the ground as hard and as fast as you can" for the EF. Respectively, none of the studies explained *why* the task or attentional focus was of relevance to the athletes involved *or* their level of familiarity with the specific focus of attention instructions, nor the degree of congruence with what they would consider to be "normal practice". While this assessment of certainty is less objective than the "quality assessment", these are important aspects of the review in terms of identifying gaps and informing readers of how they might critically interpret this systematic review's results for their professional practice; an important feature that is typically missing from previous systematic reviews (15).

DISCUSSION

Research supports the association between muscular strength and improved force-time characteristics (e.g., rate of force development and net impulse) that contribute to general sports skills such as jumping, sprinting, change of directions tasks, and sport-specific skills performance (82). There is also some evidence suggesting that the use of cognitive strategies, such as attentional focus, contributes to enhance strength performance (84). Thus, we addressed the current state of research by reviewing the methodological characteristics, intervention impact, quality of studies, and translational appropriateness of current evidence of attentional focus effects on lower limb strength tasks in the athletic population. Assessment of certainty can be considered an important difference between the current review and previously published systematic reviews in strength and conditioning, which is key to drawing conclusions based on the existing evidence and identifying future directions. In summary, our review found a limited number of studies examining lower-limb kinetics, of which none reported using Tier 5 level athletes (world class medalists or top players within top teams sport). Moreover, a mixed level of intervention impact across studies using various attentional focus strategies and a contradiction between the level of study quality according to risk of bias assessment and our assessment of certainty criteria were found.

In the authors' opinion, it is important that researchers can address the needs of specific populations, if potential solutions are to be offered. Without clarity on the population of interest, it is not certain whom the review is designed to impact, leaving potential for misleading (e.g., over- or underestimation) or uninterpretable results (24). Therefore, firstly, we decided to select studies following a new classification framework based on training volume/physical activity metrics, performance standards, and skill level competition (64). Secondly, since current reviews investigating different types of athletic performance are mainly focused on kinematic effects (i.e., long jump distance or total sprint time) (73, 96), we aimed to identify the processes underpinning these movements for a deeper understanding (EMG activities and force production). Lastly, we analyzed studies performing lower limb tasks, rather than those on the upper body, as the lower body movements are strictly related to the rates and magnitude of joint moments (90), while the upper limbs' function is to transmit (or attenuate) that force. In fact, many multi-joint sport movements originate with force being produced by contracting the lower limb muscles and the generated force is transmitted to the ground (e.g., jumping or running), object (e.g., kicking a ball), or the upper limb to move (throwing) and/or catch/intercept an object. In accounting for these factors, the review attempted to increase the focus on relevant tasks, measurements, and cognitive strategies for a specific population.

Within the limited number of studies found within this review, it is perhaps unsurprising that there was not a diverse population sample, even when considering across all of the Tiers. For example, there were notable geographical absences of participants from the Mediterranean area and less than 20% were female. Moreover, no study examined the effect of sex on any process or outcome measures. This limits the ability to adopt an evidence-informed approach when working globally and/or with female athletes where there might be important differences in professional practice demonstrated within different settings (36).

In contrast to typical lower-limb force production tasks administered within the strength and conditioning context, the experimental studies found in this review were limited in their variation.

Tasks performed across Tiers in the reviewed studies were predominantly unweighted ballistic movements. For athletes attempting to increase their lower-limb force production capability, coaches typically utilize weighted ballistic exercises. Indeed, the strength and conditioning literature has addressed these tasks through the squat jump and weightlifting pulling derivatives of Olympic lifts; however, most of the screened studies that did not meet the eligibility criteria analyzed kinematic outcomes of jumps (4, 73), movement quality during the vertical landing phase (103), sprint time (47), or snatch lift kinematics (79) in elite athletes. As such, there is a need to combine and/or triangulate different measurement techniques within strength and conditioning research in order to develop a more complete comprehension of training effects.

These findings show that current literature exclusively addresses acute intervention effects with recreationally active participants or male athletes competing at local level, with some geographical areas underrepresented. Therefore, gaps in the evidence relating to population, tasks and outcomes do not enable generalization and transfer of knowledge to the elite sport context.

Attentional Focus Conditions

In accordance with other reviews (72, 95), the studies selected adopted a comparative approach to determine which type of focus is more effective between EF, IF, and NF-control condition (general instructions regarding the task or no instructions provided), except for two studies that only compared EF and IF (49, 60). Notably, during the selection process we found several studies whereby participants performed a standing long jump and the researchers compared an IF or EF to other types of attentional focus strategies. Specifically, two of these pertained to a *holistic focus* that evoked the general feeling and timing of a movement (6, 106) and is similar to other concepts investigated such as imagining a broader, more global, IF when compared to a narrow and local IF. Another type of focus investigated was a *shifting focus*, whereby more than one type of focus was employed between the preparation and the execution phases of the trial (internal-to-external and external-to-internal) (5). Finally, the use of mental imagery to elicit an external focus of attention

(104) or to benchmark performance goals against personal ability (attainable condition) (27) were investigated as more complex iterations of the original EF condition. Despite these studies not being included in the review based on our inclusion criteria (i.e., they did not involve athletes or kinetics outcomes), it is important to note that an IF performed worse when compared to EF or at best similar to the control condition in terms of jump distance. However, it is undetermined whether an IF was more beneficial than other conditions regarding GRF and timing of the movement (e.g., RSI, which assesses an athlete's reactive strength characteristic (48)), since these measures were not available. As such, it is clear that there is a need for more research to incorporate these methodological developments within the strength and conditioning domain and with skilled populations.

Based on our selection process, research utilized a limited range of attentional foci recognized within the literature (mainly IF vs. EF) to analyze muscular strength. Instead, no studies focused on the functional components of the performance (i.e., Type 1 = optimal performance and automatic; Type 2 = functional performance and controlled (10, 33)), or the internal sensory monitoring at high intensities in endurance performance (55). To summarize, given the considerations in this section, there is a need of more studies to overcome the pure binary EF–IF paradigm (40) to analyze lower limb muscular strength outcomes in athletes.

Effects of Attentional Focus on Strength: EF, IF, and NF Control Conditions

The type of attentional focus employed had a differential impact on strength performance in only two studies (44, 53), with *trivial* to *medium* ES, but these studies did not include elite athletes. In the other 11 studies, the effects of different attentional foci were either inconsistent, not significant, or significant based on task experience. While research has supported the positive effect of EF instructions on training lower limb muscular strength (41), based on our results there is no consistency among the selected studies, plausibly as many factors contribute to the final outcome: the relevance and the nature of the instructions, task and task experience, and athlete's Tier. For instance, according to Wähnert at al., (91) the superiority of any focus depends on the sensory effects that give information about the movement goal.

Concerning the difference between EF and IF, our results are not as confident as described by Wulf (96) and not consistent with prior systematic and narrative reviews indicating that an external focus of attention is always superior to an internal focus for motor performance in any tasks, any outcomes and any sports (95). Our results seem to concur with the view of Collins et al. (28), echoing that various combinations of EF and IF would be appropriate for different tasks, with different individuals at different levels and (most importantly) for different purposes. Indeed, this is most probably why data within this field are so variable, because research does not currently account for such factors. Interestingly, Talpey at al., (83) showed that *fast leg extension instruction* (IF) was more effective than *jump height instruction* (EF) in non-athletes, regarding peak force and timing (more explosive movement) but not for jump height and peak velocity, since the downward distance (depth position) was shorter in the IF compared to EF condition. In a recent systematic review, Chua et al. (26) showed that the effectiveness of the EF condition was greater than the IF condition for performance, retention learning and transfer learning. However, Herrebrøden (46) discussed the studies included in the review of Chua et al. (26), showing that EF instructions were in the form of a *target-directed aiming task*, and IF task contained more vague information. The discrepancy that we found compared to past studies and reviews is likely due to the selection criteria of the population, the task-relevant information, and to the fact that we focused on force production rather than performance skills.

Analysis of Outcome Measures

Quality of measurement is an important aspect to take into consideration when research analyses strength outcomes related to attentional focus, and the consistency of the measures or calculation methods could influence the final results. Some studies selected analyzed performance outcomes calculated through a combination of measures or formulas (e.g., reactive strength index, jump height (30, 38, 43, 49, 57, 92)), or without describing the calculation employed (57). Importantly, the method applied could influence the results themselves. For example, during a CMJ jump using flight time measure, jump height and reactive strength index could be overestimated based on the dynamic of the landing technique (50, 66). On the contrary, to limit error factors, it is appropriate to calculate jump height on a force plate with impulse-momentum method (66, 101).

Not only does the effect of attentional focus on the task depend on the calculation method used, but also on the particular measure considered. For example, in another study selected performing CMJ (43), the EF resulted in greater peak velocity and jump height (not statistically different but with medium ES) compared to IF. By analyzing the supporting information (file with absolute values for the experiment) we found a shorter absolute displacement and contraction time during the IF condition, which would suggest a quicker execution of the jump (with perhaps a lower take-off velocity (45, 59) compared to the EF, leading to a lower jump height.

We highlight that only in one study the CMJ task showed significant effects across conditions (53). In this study the task was executed comparing different depth positions. Research performing jumps tests, in particular with wide range of motion, must take in consideration strategy variables (timing and range of displacement), and refer to a specific approach an individual may undertake to complete a task (14).

Another example of the impact of the measure chosen on the attentional focus effect is provided by the Peak vertical force or GRF. This outcome was analyzed among seven studies selected adopting unweighted ballistic tasks, yielding different results concerning the attentional focus effect across conditions. It is important to consider that peak force represents how much force was applied at one instant, but this does not mean that force was necessarily high over the whole period (e.g., during propulsive phase). In fact, Haischer et al., (42) analyzed the Dynamic Strength Index (the ratio between dynamic and isometric tasks) showing that the ability to express force over time (i.e., impulse) is a better predictor of dynamic performance compared to peak force. Moreover, McBride et al., (63) found no significant correlation between peak force and jump height in SJ and CMJ, with various loads and depths. Finally, peak force is proved to be a useful metric to measure interlimb asymmetry in injured athletes (12, 13), rather than assessing muscular strength performance in unweighted ballistic tasks. In conclusion, taking inspiration from Bishop et al, (14) and Harry at al., (45) when assessing the effects of attentional focus for ballistic tasks we recommend that consideration be given to the kinetics outcomes displacement, duration of braking/propulsive phase, and mean net force or net impulse, and the performance outcomes jump height or jump momentum, while for non-ballistic tasks displacement and net impulse should be considered.

In summary, to minimize inconsistent results, studies investigating attentional focus should use reliable and appropriate outcome measures.

Muscular Mechanisms

Our review also focused on identifying the muscular actions investigated across the attentional focus literature based on our PICOS framework. DJ was the main task examined, with the muscle action influenced by fast SSC mechanisms with GCT < 250ms (86), followed by CMJ task. The involvement of fast SSC or slow SSC (GCT > 250ms) mechanisms in CMJ depends on several factors such as the amplitude of the countermovement, the individual capability to reduce muscle slack, and quick increase stimulation performing small-amplitude countermovements (88, 89). However, most studies selected did not provide clear information regarding the range of motion (countermovement depth) performing the CMJ task except for one (53). This lack of information does not allow the contribution of fast or slow SSC mechanisms during the execution of the attentional focus instructions to be investigated. Few studies selected compared attentional focus instructions during the ten meters acceleration task, which involved the *pretension* mechanisms with relatively long GCT (> 250ms), and large joint angular displacement (21). Another muscular mechanism analyzed was the isokinetic one (39, 60), involving a single joint pattern (knee extension and hip-external abduction). Notably, the isokinetic machine task does not represent the muscular action involved in the sports played by athletes analyzed in the studies with this task (intermittent team sports).

Regarding isometric muscle actions, research (78) distinguishes two different modes of performance: *Pushing/Pulling* (PIMA) and *holding* (HIMA) isometric. Our review found only one study performing the PIMA mechanism (IMTP (44)).

We highlight that research on attentional focus concentrated on studies investigating mainly muscular actions influenced by SSC, pre-stretch, and pretension mechanisms, while no studies evaluated just concentric (e.g., unweighted SJ or with various loads) or augmented eccentric muscular mechanisms (e.g., flywheel resistance technology, (3)).

Assessment of Certainty of Findings

Overall, the quality assessment was on average "excellent"; however, despite a low risk of bias score (16 out of 20 points), we found many methodological issues that are consistent with contemporary critiques within the attentional focus topic literature. Due to the absence of a manipulation check in the majority of studies (25), we cannot state with certainty that participants were adhering to the specific instruction for each condition. This point is important because recent evidence has shown that athletes sometimes demonstrate a degree of independence over their attentional focus strategy, even when asked to direct their focus to a specific IF by their coach (69). In addition, according to Yamada et al. (102) athletes that were interrogated using a manipulation check did not frequently use an EF either. Of the few studies meeting the inclusion criteria of this review, the issue of adherence to the instructions was reported within one of the studies when administering a manipulation check (49). As such, the veracity of these strategies to impact on performance or learning must be called into question due to not actually knowing what participants were attending to.

A particular issue that is also worth raising relates to the quality of the attentional focus instructions, of which there are several components to consider. Firstly, instructions direct participants' attention to a specific aspect of the movement (IF) or movement effect (EF), the *what* constituent of the instruction, but in doing so, the instruction also expresses *how* that attention should be applied. These two components have been addressed within theoretical motor control research as key features of the motor representation (76) and explained as poorly operationalized within research investigating the effect of anxiety on motor skill execution (22). Whether the intention of the coach is to increase performance by increasing the reliability of an already learnt skill that has been established through previous experience with the movement task in the same environment, or by introducing important new movements to the learner as part of the acquisition process, consideration towards the content and modality (e.g., kinesthetic, visual, or verbal) needs to be included within any decision-making process. When these factors are incongruent with the participant's normal execution process, understanding, not suitable for a particular task, and/or skill status, this can disrupt the performance regardless of whether an IF or EF has been instructed (62). We suggest that the same limitation applies to the studies reviewed here in that there was little or no consideration of why an instruction was provided and in that particular way. Secondly, the amount of information provided within the verbal instructions differed in several studies. Again, evidence has shown that the number of instructions and length or instruction creates an unfair comparison between conditions when these differ (18). Differences in the cognitive loads imparted, relevance, and familiarity of instructions, for instance, can misrepresent the effectiveness of an intervention (15) which is particularly problematic when studies do not meaningfully compare experimental conditions to what is currently considered best professional practice within the applied field. Therefore, the simple idea of comparing an IF with an EF, as researchers have often done, is far too simplistic and neither representative of the applied challenges faced by coaches and athletes, nor the cognitive mechanisms that support learning and performance.

Overall, these criticisms indicate a lack of *translational* certainty within this body of research and a need to apply greater criticality when designing studies for practical use with athletes in the future. This might include whether or not the athletes already perform the exercise as part of their training and, if so, what their normal focus is, and the way in which they execute the tasks. Therefore, taking these arguments into account, an IF may represent a beneficial cognitive strategy when empirically compared to an EF, despite the seemingly unanimous evidence against it (95). Crucially, our findings show consistency between attentional focus research in sport and studies employing different attentional focus strategies for lower-limb force production tasks; thus, suggesting that the translational issues are driven by the attentional focus literature and not the strength and conditioning domain.

Limitations

This review is not without limitations. First, the lack of standardized instructions used in some of the studies and the variability among the tests used did not allow us to perform a meta-analysis. A meta-analysis would have provided a more precise estimate of the results; therefore, future studies should specify and standardize the instructions provided to the participants. Secondly, many of the articles found in the literature assessed recreationally active populations (e.g., amateurs and university students). Third, the majority of the participants enrolled in the studies currently present in the literature are male, which limits the application of the findings when considering female athletes.

Lastly, the criteria for the Assessment of Certainty were derived from contemporary articles within the field (16). While these criteria could be considered to be subjective in nature because they did not use an evaluation scale, the methodological characteristics that were evaluated have been repeatedly accepted as relevant to advancing knowledge and professional practice by scholars within this field (28). Furthermore, the identification of these characteristics within the identified studies can be considered equally as definitive as the items included within the quality assessment scales (e.g., information about manipulation checks, the justification for the experimental manipulation).

PRACTICAL APPLICATIONS

The results of our systematic review show few experiments analyzed the effects of the focus of attention in elite athletes and there is limited evidence on each type of strength characteristics and muscle action involved. Based on the evidence gathered, there is a lack of consistent high-quality evidence to support the superiority of any forms of attentional focus strategy (EF or IF) compared to a control condition or a condition of no focus of attention (NF) on lower limb strength tasks in athletes. These findings may be due to the instructions being often task-irrelevant, and not congruent with what S&C coaches and athletes would consider to be "normal practice". Researchers and practitioners should cautiously implement forms of attentional focus strategy aiming at increasing lower limb strength performance and therefore, take training decisions based on the currently limited evidence and on their experience and muscle actions investigated (e.g., no studies involved resistance training movements and flywheel-based exercises), until new coherent evidence is available.

Furthermore, this review reports that the available research studies were mainly located in the USA and North Europe, with sport athletes from other areas (e.g., Mediterranean area and Asia) not studied. It is possible that athletes of different geographical areas and with different backgrounds could respond differently to attentional focus strategies.

Future studies need to explore attentional strategies that promote individual task-relevant information rather than a binary comparative approach to determine which type of focus is more effective, in order to provide clearer recommendations to practitioners and coaches to enhance muscular strength performance.

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statistical analyses and reviewing/editing a draft of the manuscript; MB2 contributed the research concept and study design, data collection and reviewing/editing a draft of the manuscript.

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