Title: The match-play and performance test responses of soccer goalkeepers: A review of current literature

Running Head: Performance responses of soccer goalkeepers

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ABSTRACT

Goalkeepers are typically the last defensive line for soccer teams aiming to minimise goals being conceded, with match rules permitting ball-handling within a specific area. Goalkeepers are also involved in initiating some offensive plays, and typically remain in close proximity to the goal-line while covering ~50% of the match distances of outfield players; hence, the competitive and training demands of goalkeepers are unique to their specialised position. Indeed, isolated performance tests differentiate goalkeepers from outfield players in multiple variables. With a view to informing future research, this review summarised currently available literature reporting goalkeeper responses to: 1) match-play (movement and skilled/technical demands), and 2) isolated performance assessments (strength, power, speed, aerobic capacity, joint range of motion). Literature searching and screening processes yielded 26 eligible records and highlighted that goalkeepers covered ~4-6 km on match-day whilst spending ~98% of time at low movement intensities. The most decisive moments are the 2-10 saves·match^{-1} performed, which often involve explosive actions (e.g., dives, jumps). Whilst no between-half performance decrements have been observed in professional goalkeepers, possible transient changes over shorter match epochs remain unclear. Isolated performance tests confirm divergent profiles between goalkeepers and outfield players (i.e., superior jump performance, reduced $\dot{V}O_{2max}$ values, slower sprint times), and the training of soccer goalkeepers is typically completed separately from outfield positions with a focus primarily on technical or explosive drills performed within confined spaces. Additional work is needed to examine the physiological responses to goalkeeper-specific training and match activities to determine the efficacy of current preparatory strategies.

KEY POINTS

- Soccer goalkeepers cover ~4-6 km on match-day, and appear not to experience between-half reductions in physical performance as the match progresses. Transient within-match changes in physical and technical performance (i.e., performance over smaller epochs), and acute physiological responses during soccer match-play, remain to be profiled in goalkeepers.
- Saves (preventing a goal) occur relatively infrequently during a match (2-10 #·match^{-1}) but intuitively represent the most important phases of play and should remain a major training focus for soccer goalkeepers. Goalkeepers also occupy an important role in ball-distribution and more information is

required as to the physiological impact (i.e., fatigue response) from high-velocity jumping, diving, and kicking actions routinely performed.

- Performance during isolated tests may discriminate soccer goalkeepers from other playing positions. However, specific performance tests for goalkeepers should be determined based on the unique physical and mental demands of their position; demands which remain to be determined.

1.0 INTRODUCTION

The goalkeeper's primary role in soccer is to protect his/her team's goal, whilst a secondary purpose lies in ball-distribution during the initiation of an attack [1]. As the objective of soccer is to out-score the opposition, it stands to reason that the demands placed upon goalkeepers have the potential to directly influence the outcome of a match. Indeed, as the only players permitted to legally handle the ball (when inside the penalty area) whilst the game is 'live', their positional role is not akin to that of other outfield playing positions. Therefore, goalkeepers may possess a unique physiological profile and it is likely that further details about their match-play and training demands, in addition to performances throughout isolated testing scenarios, would benefit practitioners seeking to optimise training prescription for this bespoke playing population.

In contrast to outfield players who cover ~10-12 km during a 90 min match [2-10], including a sprint every ~90 s [4], soccer goalkeepers may cover 4-6 km on match-day and perform only 2 short sprints in this time [11-13]. Conversely, empirical observations suggest that outfield players are rarely required to pass the ball distances ≥50 m, whereas goalkeepers in their offensive role may make 8-14 kicks·match^{-1} into the opponent's half [14]. Such high-velocity actions may contribute substantially to a goalkeeper's overall match-load [2] and thus elicit a unique physiological response and post-match recovery profile when compared with other playing positions. However, limited attempts have been made to quantify the physical demands and/or physiological responses faced by soccer goalkeepers during training and competition.

Empirical observations suggest that soccer goalkeepers engage in an extended, individually-led pre-match warm-up (~45-60 min) that incorporates a range of technical stopping and catching drills. During a match, goalkeepers typically remain close to the goal-line and touch the ball only when defending an attack, re-starting the game via a goal-kick or free-kick, or re-distributing the ball following a 'back-pass' from a team-mate. Barring injury, goalkeepers are seldom substituted, therefore must be conditioned to maintain their physical and skilled performance for the full duration of 90 min, or potentially 120 min plus penalties in the case of specific tournament matches. The unique demands of the position mean that their training appears to be largely technically focused and typically involves multiple goalkeepers (i.e., 3-4) from a squad who work within confined spaces and separately from outfield players. Empirical evidence supports the requirement for goalkeepers to engage with both training- (i.e., goalkeeping training, training shooting, and small sided games) and game- (i.e., game, pre-game shooting, personal pre-game warm-up) specific scenarios over the course of a competitive week.

Given the paucity of research attention afforded to this unique position, presumably due to challenges of recruiting sufficient sample sizes, this review sought to systematically appraise literature which has profiled the performances of soccer goalkeepers during match-play and isolated performance tests, with a view to informing practice and identifying opportunities for future research.

2.0 METHODOLOGY

Searches were conducted in the PubMed online database during March 2018. Key words relating to the sport (i.e., 'soccer', 'football') and position (i.e., 'goalkeeper', 'goal keeper', 'goal-keeper', 'keeper', 'goalie', 'GK') were entered in various combinations. Filters included: original publications in scientific journals published before March 2018, for which full-texts were available in English. Following removal of duplicates and screening of abstracts, the remaining full-text articles were assessed using a narrative review strategy. Articles were excluded on the basis that they: a) included no male participants, b) included no identifiable group with a mean age ≥16 years, c) did not report any aspects of goalkeepers' physical or skilled performance, d) focused on only isolated scenarios (e.g., penalty-kicks) within match-play, e) included insufficient methodological details, and/or f) were review articles. Articles identified through other sources (e.g., those known to the authors) and references cited in the retrieved articles were also considered for inclusion.

3.0 FINDINGS AND DISCUSSION

The original search strategy yielded 132 results. Following removal of duplicates, and screening of articles according to the six exclusion criteria, 23 records were retained. A further three records already known to the authorship group were included such that 26 records satisfied the criteria. Records were pooled into seven main themes, with eight documenting aspects of the match-day performance of soccer goalkeepers (table I), 12 investigating variables related to goalkeepers' strength and/or power (table II), 11 records each profiling goalkeepers' linear or multidirectional sprint speeds (table III) and aerobic capacities (table IV), five reporting the outcomes of soccer-specific skill assessments (table V), and three records which investigated other aspects of goalkeepers' performance, such as joint range of motion (ROM) and motor co-ordination (table VI). Records incorporating multiple aspects were included in more than one category.

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3.1 Match performance of soccer goalkeepers

Whilst some authors have used notational analysis or data from official tournament websites to provide counts of technical actions, others have employed various forms of player-tracking in an effort to quantify the physical demands faced during match-play (table I). Accordingly, the eight records that have investigated the on-field performance of soccer goalkeepers have been categorised into those focusing on either goalkeepers' physical or technical performance.

3.1.1 Physical performance

It is widely reported that outfield players cover ~10-12 km·match^{-1} [2-10] or up to 14 km if matches require extra-time [15], but unsurprisingly goalkeepers seldom appear to achieve such distances. When observed via a multi-camera tracking system, English Premier League (EPL) goalkeepers recorded 5611 m·match^{-1} [11], whereas international goalkeepers elsewhere have averaged 4183 m·match^{-1} [12] and elicited rates of 46 m·min^{-1} [16]. Additionally, a Dutch professional goalkeeper on match-day (including warm-up) accumulated 5985 m [13]. Irrespective of differences between studies, these distances represent ~50% of those covered by outfield players [2-10], and may explain why no between-half declines in total distance (TD) have been observed within any intensity threshold for international or EPL goalkeepers [11, 12]. Indeed, where outfield players are concerned, the greater between-half decrements in high-intensity running (HIR) for midfielders compared to other positions [8, 17], and for 'top-class' versus 'moderate-class' players [4], indicates that the magnitude of performance decline is positively influenced (η^2 = 0.04-0.10) by the overall amount of activity being performed [17]. Notably, the disproportionate increase in the number of goals scored during the final 15 min of match-play [18, 19], and suggestions that progressive fatigue of outfield players may increase the number of scoring opportunities, means that the ability of goalkeepers to maintain physical and technical proficiency for the duration of match-play may be crucial. Such conjectures may be particularly relevant when considered alongside empirical observations that goalkeepers report high levels of mental fatigue over the course of a match, which has demonstrated the potential to influence both physical and skilled performance [20]. In addition, goalkeepers may face lengthy periods during which they are not directly involved with play, which may deleteriously affect their ability to subsequently produce high-degrees of muscular force. Indeed, half-time research in outfield players has demonstrated that declines (2°C) in muscle (T_m) and core (T_{core}) temperature following ~15 min of inactivity are accompanied by significant reductions in countermovement jump (CMJ) peak power output and sprinting performance [21-23].

In a study of EPL goalkeepers, only 1% of TD (56 m) consisted of high-speed running (HSR; defined as 19.9-25.2 km·h^{-1}), whereas the majority of distance (4025 m) consisted of walking, with only 10 high-speed runs and 2 sprint (>25.2 km·h^{-1}) actions performed per match [11]. Although empirical observations posit that these metrics may be heavily influenced by other contextual variables (e.g., opposition quality, playing formation etc.), no study has investigated such suggestions to the authors' knowledge. When international goalkeepers' activities were categorised by intensity, ~98% of time was spent in the low-intensity threshold, compared with ~83% for outfield players [16]. Moreover, goalkeepers on match-day (including the warm-up) may perform as few as 11 and 5 high-intensity (defined as >3 m·s^{-2}) accelerations and decelerations, respectively [13]. Conversely, professional outfield players perform up to 14 high-intensity accelerations and 24 high-intensity decelerations in a single 45 min half [3]. However, caution must be exercised when interpreting traditional GPS metrics in isolation, as other physiologically demanding actions such as high-velocity kicking, jumping, throwing, and diving are likely to increase the overall physical load experienced by goalkeepers [2].

Other studies have used observational techniques to identify the type of activities performed by goalkeepers during match-play. During the 2002 World Cup, the most common movement preceding a technical action was 'displacement' (19 #·match^{-1}), with movements forward (9 #·match^{-1}) being the most frequent [24]. Dives (6 #·match^{-1}) and jumps (4 #·match^{-1}) were performed less often, but appear empirically to represent moments of paramount importance during a game (i.e., to prevent scoring opportunities). When Italian professional goalkeepers were observed during 10 official matches, a total of 52 forward and 40 lateral running actions were performed per game, moving on average 3.6-3.7 m [25]. These players covered 270 m·match^{-1} at high-intensities, which exceeds the HSR distances (56 m) observed for EPL goalkeepers [11]. However, such inconsistencies may be attributable to methodological differences, as the former study [25] defined 'high-intensity' to include any action in response to a potential threat on goal, rather than the velocity thresholds (i.e., 19.9-25.2 km·h^{-1}) employed in the EPL study. In addition, Division C Italian goalkeepers covered 60% more high-intensity distance than those one division below [25].

The substantially lower distances covered by goalkeepers when compared with their outfield counterparts may have important implications for training and recovery practices. Observations that physical performance is at least maintained between halves [11, 12] suggest that goalkeepers accumulate minimal amounts of physical fatigue during match-play. In addition, a professional goalkeeper has been reported to cover 2553–3742 m at 43–49 m·min^{-1} during an in-season training session [13], compared with 4203–6515 m at 74–89 m·min^{-1} for other positions [26]. Despite covering less TD during training when compared to match-play, goalkeepers may record equivalent or greater values for high-intensity accelerations (12 #·match^{-1}) and decelerations (7 #·match^{-1}), and GPS-derived player loading metrics during a midweek training session than on the whole of match-day itself [13]. It is therefore possible that for some specific variables, goalkeepers experience lower physical loads on match-day when compared to certain training types (e.g., the number of dives performed in match-play may be less than in a shot stopping-specific training session). In light of the above, further investigation into the physiological demands of various goalkeeper-specific training modalities would aid practitioners wishing to balance adaptive stimulus and recovery when periodising training loads.

3.1.2 Technical performance

The unique nature of the position means that goalkeepers must possess different skills from those of other players who are not required to save, catch, block, punt, or punch the ball. However, studies investigating goalkeepers' technical performance during match-play have reported inconsistent results, perhaps due to differences in methodology, terminology, and the inherent influence of situational factors on the pattern of soccer match-play [27-29]. De Baranda et al. [24] reported that international goalkeepers performed 23 defensive technical actions over 90 min, of which the most frequent actions were 'saves' (i.e., blocking a scoring opportunity; 10.0 #·match^{-1}). Although an investigation of Spanish professional goalkeepers reported a lower incidence (2.9 #·match^{-1}) of saves [14], these studies reinforce that the main defensive role of soccer goalkeepers is preventing scoring opportunities and confirm that these events occur relatively infrequently during a match, although they may be modulated by various contextual factors.

When league standing was used to group Spanish La Liga clubs into high, intermediate, and low-standard teams, goalkeepers on high-standard teams (i.e., top six league positions) made fewer saves than those on low-standard teams (2.9 vs 3.4 #·match^{-1}) and also performed fewer touches of the ball, passes, interceptions, clearances, and catches [14]. Such findings are analogous to observations in outfield players in which league position influences the number of technical involvements during match-play [30]. However, whilst outfield players on higher-standard teams may perform technical actions (i.e., dribbles, shots, passes, and tackles) with greater frequency than their lower-standard counterparts, the mostly defensive nature of the position means that for goalkeepers this relationship appears to exist in reverse [14].

With regards to the influence of opposition, goalkeepers on low and intermediate-standard teams made more saves when facing high-standard opposition (i.e., 4.2 and 4.3 #·match^{-1}, respectively) than when facing other low-standard teams (i.e., 2.9 and 3.4 #·match^{-1}, respectively) [14]. Conversely, goalkeepers on high-standard teams made more saves when facing low-standard opposition than when facing intermediate or other high-standard teams. Such counterintuitive findings may be attributable to differences in playing style/formation when high-standard teams face lesser opposition, whereby adopting a more expansive approach may create opportunities for the opposition to counter-attack. It is also possible that in an effort to mitigate the effects of fatigue across a season, managers of high-standard teams may field a 'second-string' starting 11 when playing against teams perceived to be of a lower-standard. Speculatively, the potentially weakened defensive line-up may permit a greater number of shots on goal than when first-choice players are selected.

As may be expected, La Liga goalkeepers on low-standard teams were required to make more saves in matches that they lost (3.9 #·match^{-1}) compared to those drawn or won (2.9 #·match^{-1}), whereas match-outcome exerted no influence on the number of saves for goalkeepers on teams classed as intermediate or high-standard [14]. Finally, low and intermediate-standard goalkeepers made more saves when playing away (3.7 and 4.1 #·match^{-1}, respectively) than when playing at home (3.1 and 3.2 #·match^{-1}), yet location had no effect for high-standard goalkeepers. Therefore, whilst professional goalkeepers may make relatively few saves (2-10 #·match^{-1}) over the course of 90 min [14, 24], a number of factors appear to modulate this response. In addition, because the ability to obstruct shots on goal has clear relevance to the overall score, these actions may be considered amongst the most important moments during a game. Accordingly, empirical observations suggest that saves comprise a substantial portion of goalkeepers' position-specific training, as they seek to minimise the number of goals conceded (0.2-0.4 #·match^{-1}) as a direct result of goalkeeper error [31].

3.2 Strength and power of soccer goalkeepers

Twelve eligible records have investigated goalkeepers' force-production capabilities (table II), with the majority employing jump protocols or assessments of strength during isometric or isotonic muscle actions. Given the synergistic role of the hamstrings and quadriceps during soccer-specific actions such as kicking and running, it is unsurprising that these muscle groups have been the primary focus of many investigations.

When tested using isokinetic dynamometry at an angular velocity of 60°·s^{-1}, professional Brazilian goalkeepers demonstrated greater concentric knee flexor and extensor peak torque (PT) compared with all outfield positions except for centre-backs [32]. However, when knee flexion was tested eccentrically, no differences existed between these positions. This latter finding may be attributable to the role of the hamstring musculature acting eccentrically during sprinting and decelerating tasks [33], and related to the additional sprinting volume, and thus development of eccentric strength, in outfield players compared with goalkeepers during training and match-play [7, 8, 11, 13, 26]. Brazilian under-17 provincial players also performed concentric knee flexion and extension at 60°·s^{-1}, and whilst goalkeepers generated higher PT than all outfield players except defenders, this was only true in their non-preferred limb [34]. Conversely, when the angular velocity was increased to 300°·s^{-1}, goalkeepers and defenders produced higher flexion and extension PT in both limbs versus all other positions [34]. The differential findings for preferred versus non-preferred limb may indicate greater bilateral symmetry for goalkeepers and defenders than players in other positions. Indeed, whilst goalkeepers in this investigation demonstrated between-limb deficits in PT of 1.5-3.7% when tested at 60°·s^{-1}, the corresponding deficits were 11.3% and 10.0% for fullbacks and midfielders, respectively [34]. In contrast, a study of Greek professional players, identified no influence of playing position on isometric grip, leg, or leg and back strength [35].

Using a linear position transducer, professional Icelandic goalkeepers recorded higher concentric power outputs during Smith machine back squats (1451 vs 1309-1400 W), when compared with all outfield positions [36]. However, no differences were observed for squat jump (SJ; 0.36-0.38 m) or CMJ (0.38-0.39 m) height; perhaps because the goalkeepers were significantly heavier than their outfield counterparts. Similarly, sub-elite Spanish goalkeepers achieved similar SJ (0.39-0.42 m), CMJ (0.41-0.43 m), and drop jump (DJ; 0.41-0.44 m) heights relative to outfield players of the same level [37]. No differences in CMJ height (0.37-0.38 and 0.30-0.32 m) between positions were observed either for under-19 Portuguese [38] or under-18 English players [39]. Moreover, no differences in CMJ height (0.36-0.38 m) or standing broad jump distance (2.19-2.30 m) were identified amongst professional Belgian under-19 goalkeepers and outfield players [40], and Nikolaidis et al. [35] reported homogeneity across positions (0.37-0.41 m) when CMJ was performed with an arm-swing.

Other studies have suggested differential jump performance between goalkeepers and other positions. Using pooled data from professional, semi-professional, and amateur Norwegian players, Haugen et al. [41] highlighted greater CMJ height (0.40 vs 0.38 m) for goalkeepers versus midfielders. Additionally, professional Belgian goalkeepers jumped higher in the SJ (0.42 vs 0.39 m) and CMJ (0.46 vs 0.41 m) than fullbacks and midfielders [42], whilst SJ (0.47 vs 0.42-0.44 m) and CMJ (0.49 vs 0.44-0.45 m) performances were superior for professional Croatian goalkeepers than all outfield groups [43]. Conflicting findings between studies may be reconciled with reference to the populations under investigation. Indeed, it appears that jump performance is largely unable to distinguish goalkeepers from other positions where under-19 players are concerned [38-40], whereas the greater jump heights demonstrated by senior professional goalkeepers versus outfield players [41-43], suggest the importance of explosive power for goalkeepers at the highest level.

Empirical observations also suggest that match demands may differ between playing levels and according to opponents' playing 'style'. Goalkeepers in competitions where opposition teams frequently employ high crosses as an attacking ploy may be required to jump higher and more frequently than those where the ball is mostly kept low to the ground. Such observations may be important from a training perspective as practitioners must ensure that goalkeepers are physically prepared for the rigours of match-play, with particular reference to the specific demands faced. The influence of playing level on goalkeepers' force production is further highlighted by observations that elite under-19 goalkeepers generated greater knee flexion (117 vs 91 Nm), and extension (236 vs 202 Nm) PT, and tended to perform better in the SJ (0.41 vs 0.34 m) and CMJ (0.42 vs 0.33 m) than their sub-elite counterparts [44]. However, the implications of strength/power capacity for player selection are less apparent, and no difference in CMJ performance (0.41-0.42 m) was identified amongst sub-elite goalkeepers, between those selected and those 'dropped' at the end of the season [37].

Nikolaidis et al. [35] assessed the anaerobic power of senior Greek players using three cycle ergometer assessments and observed no differences in power output between goalkeepers and outfield players in any of the three protocols. However, when corrected for body mass goalkeepers produced lower mean power (8.2 vs 8.8-9.1 $W \cdot kg^{-1}$) than their outfield counterparts during a Wingate test. Nevertheless, caution should be exercised when drawing conclusions from cycling assessments, as these modalities bear little resemblance to the jumps and dives performed by goalkeepers during match-play.

3.3 Linear and multidirectional speed of soccer goalkeepers

The ability to quickly cover ground is crucial for outfield soccer players, who may perform 150-250 brief, intense actions during match-play [4, 5]. Whilst goalkeepers may only perform 2 $sprints \cdot game^{-1}$, each typically <10 m in length [11], these actions may represent important phases of play that are directly linked to opportunities to influence the score. With this in mind, 11 eligible records (table III) have investigated the linear and/or multidirectional speed capabilities of soccer goalkeepers during isolated assessments.

Most studies employing short (≤30 m) straight-line sprints have identified significant differences in performance between goalkeepers and outfield players. English professional under-18 goalkeepers were slower over 10 m and 20 m (1.65 and 2.94 vs 1.60 and 2.84 s) than wide midfielders [39], whilst under-19 Belgian goalkeepers took longer than forwards (4.44 vs 4.28 s) to complete their fastest of four 30 m sprints [40]. Studies in senior players have shown similar findings, with sub-elite Spanish goalkeepers achieving slower 30 m times (3.83 vs 3.51 s) than forwards following a flying start [37], and professional Belgian goalkeepers completing the first and second 5 m of a 10 m sprint in 1.46 and 0.76 s, compared with forwards' 1.43 and 0.72 s, respectively [42]. Likewise, in senior Norwegian players, goalkeepers achieved lower 0-20 m speeds (7.10 vs 7.35 and 7.23 $m \cdot s^{-1}$) than forwards and defenders [41]. The only study to observe differential sprint performance between goalkeepers and *all* outfield positions highlighted slower 10 m (2.35 vs 2.03-2.23 s) and 20 m (3.51 vs 3.28-3.43s) times for professional Croatian goalkeepers versus their outfield counterparts [43].

Although one investigation reported no difference in 30 m sprint time between goalkeepers and any outfield position [45], the majority of studies highlight goalkeepers as amongst the slowest players within a squad. Interestingly, two studies in which professional goalkeepers were slower over 10-30 m reported no such positional differences during the initial 5 m for players of either senior (1.06-1.08 s) or under-19 (1.39-1.47 s) standard [40, 43]. Although these findings conflict with a study of professional Belgian players [42], it is plausible that a goalkeepers' high capacity for lower-body force production enables them to match outfield players during the initial acceleration phase [36, 41, 43]. Such observations are potentially important given the requirement for goalkeepers to perform short, explosive movements in response to opposition attacks. Indeed, the ability to rapidly cover distances of 0-10 m appears intuitively to represent an important training focus.

When performance throughout repeated sprint protocols has been assessed, results have been conflicting. Whilst professional goalkeepers took longer (26.0 vs 25.4 s) to complete 6x20 m than outfield players [46], a protocol involving 7x30-35 m sprints, each incorporating a slalom, has produced no differences in total (53.5-54.6 s) or mean (7.5-7.7 s) sprint time between goalkeepers and outfield players in samples of Portuguese under-19 [38], or amateur Turkish [47], players. Moreover, Kaplan et al. [47] demonstrated goalkeepers' abilities to maintain performance over seven sprints when separated by 25 s of active recovery, as no sprint was significantly slower than any other. However, notwithstanding the possibility for goalkeepers to face repeated attacks on goal, the ecological validity of repeated sprint assessments to evaluate soccer-specific fitness may be called into question for goalkeepers. Indeed, the requirement to repeatedly cover distances >10 m appears inapplicable to goalkeepers who remain close to their goal and perform 2 sprints during an entire match [11]. Given such demands, it seems that very short-duration explosive power is of paramount importance for executing the dives and jumps that characterise the role. Notably, empirical observations suggest that goalkeepers may be required to make multiple dives (including returning to feet between dives, and possibly kicking long distances thereafter) within a short time-period during sustained attacks by the opposition. Therefore, it may be that repeated dive, jump, or kicking assessments are more specific to this playing population and may enable the responses to very intense periods of match-play to be quantified.

In addition to linear sprints, assessments have been made of goalkeepers' multidirectional speed. As was the case for straight-line running, sub-elite Spanish goalkeepers took longer (5.0 vs 4.6 s) than forwards to complete a pre-planned slalom test [37]. Similarly, professional Belgian goalkeepers were slower (12.3 vs 12.0 and 12.1 s) over a 5x10 m shuttle-run than either forwards or midfielders [42], and Portuguese under-19 goalkeepers were slower than outfield players (18.6 vs 18.2 s) over 10x5 m [38]. In contrast, no between-position differences in T-test performance (9.1-9.3 and 8.4-8.6 s) were identified amongst professional under-18 [39] or under-19 [40] players. Taskin et al. [45] implemented a 'four-line' sprint protocol in a cohort of professional Turkish players and observed comparable performances between goalkeepers and outfield positions. It should be noted however, that although goalkeepers may be required to rapidly change direction during a game, because they operate primarily within a small area [24] and must respond to unpredictable stimuli, pre-determined multidirectional courses may not fully reflect the demands of match-play.

When comparing between playing levels, Rebelo et al. [44] reported similarities amongst Portuguese under-19 players, but large effect sizes were observed alongside a tendency for elite goalkeepers to outperform their sub-elite counterparts over 5 m (1.0 vs 1.2 s), 30 m (4.3 vs 4.6 s), and during the T-test (9.0 vs 9.4 s). No differences in flying 30 m sprint (3.8-3.9 s) or 30 m slalom (5.1-5.2 s) times existed between goalkeepers from a sub-elite Spanish club who were successful or unsuccessful in being retained at the end of season selection process that recruited players for the subsequent playing season [37].

3.4 Aerobic capacity of soccer goalkeepers

Table IV outlines the 11 records that sought to determine the aerobic capacity of soccer goalkeepers. Irrespective of population, most investigations report that relative to body mass, goalkeepers' maximum oxygen uptake falls below that of their outfield counterparts. During incremental treadmill tests, professional goalkeepers have consistently recorded lower $\dot{V}O_{2max}$ values (50-57 vs 56-63 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) than outfield players [36, 42, 43, 46]. Notably, a study of professional Cypriot players [48] observed lower values for goalkeepers (51.5 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) only when compared with midfielders and wingers (56.1 and 56.5 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$). A lower $\dot{V}O_{2max}$ has also been reported for Japanese high school (54.2 vs 61.4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) and sub-elite Spanish goalkeepers (48.4 vs 57.7-62.4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) when compared with their outfield counterparts [37, 49]. The lower values in the latter study compared with others may be attributable to inconsistent methodologies, as this investigation [37] estimated $\dot{V}O_{2max}$ from a cycle ergometer test, rather than during incremental treadmill running. It is plausible that because soccer players are more accustomed to on-feet modalities, they may demonstrate reduced efficiency during cycling tests, and exhibit lower $\dot{V}O_{2max}$ values as a consequence [50].

Other studies have assessed aerobic capacity by measuring TD during various forms of multi-stage fitness test. Inferior performance has been reported for goalkeepers compared with outfield positions in both professional Belgian [40], and regional Portuguese [38] under-19 players, although a study of professional English under-18 players observed no difference in TD between positions [39]. Finally, whilst the use of standardised protocols allows cross-study comparisons, the only investigation to directly compare multi-stage fitness test performance between different playing levels observed a tendency towards greater TD (992 vs 647 m) for elite versus sub-elite under-19 goalkeepers [44].

It therefore appears that goalkeepers at all levels possess lower maximal aerobic capacities than outfield players, which seems in keeping with their vastly different match-play [11-13] and training [13, 26] demands. However, because goalkeepers are required to perform less overall running than outfield players and appear not to suffer within-match declines [11, 12], enhancing maximal aerobic capacity may not be a priority for goalkeepers whose training appears to focus on technical proficiency and short-explosive movements within confined spaces. That said, established relationships between aerobic capacity and recovery between high-intensity efforts [51] highlights a possible role of aerobic conditioning for players who may benefit from faster recovery rates and an enhanced ability to maintain performance over repeated high-intensity actions.

3.5 Soccer-skill performance of soccer goalkeepers

Five eligible records (table V) assessed the performance of goalkeepers in tests of soccer-specific skill. In professional Turkish players [45], professional under-19 Belgian players [40], and regional under-19 Portuguese players [38], goalkeepers displayed worse dribbling performance than outfield positions. Likewise, goalkeepers scored lower than outfield players on a test of passing proficiency [38], and performed worse than forwards and defenders when heading accuracy was assessed [52]. Such findings are to be expected, as goalkeepers are rarely required to dribble or head the ball during a match. However, in under-19 Portuguese players, no between-group differences were observed for ball control, and goalkeepers actually outperformed their outfield counterparts during a test of shooting accuracy [38]. Whilst such findings appear surprising, under-19 goalkeepers may engage in less position-specific training than senior players; leading to less differentiation between positions, and the fact that youth goalkeepers tend to mature sooner than outfield players [39, 40] may explain their improved shooting accuracy despite shooting not forming part of the goalkeeper's role. Additionally, because goalkeepers typically train separately from outfield players, empirical observations suggest that they are often required to practice shooting against each other in order to simulate saves during match-play. Unfortunately, only one study has directly compared skilled performance between goalkeepers of different playing levels, and observed no significant difference for ball control or dribbling speed between elite and sub-elite under-19 goalkeepers [44]. Whether differences exist in senior goalkeepers with greater position-specific training experience remains to be determined.

3.6 Other aspects of soccer Goalkeepers' performance

Three records (table VI) compared joint ROM between goalkeepers and outfield players, and no differences in sit-and-reach test performance (0.23-0.27 m) were observed [35, 40]. In contrast, whilst homogeneity amongst positions existed for the hamstrings and adductors, professional Icelandic goalkeepers displayed greater passive range in the hip flexors (181.4 vs 178.5-179.0°) and rectus femoris (138.5 vs 134.0-134.7°) than their outfield counterparts [36]. Although the reasons for these findings remain unclear, such reports highlight the differing physiological profiles between goalkeepers and outfield players. Notwithstanding, Deprez et al. [40] administered a box-moving test to assess non-specific motor coordination and observed no differences between goalkeepers and outfield positions.

4.0 CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Soccer goalkeepers occupy a unique positional role and demonstrate different physiological profiles from outfield players. Goalkeepers cover less TD and HIR, and perform fewer sprints, accelerations and decelerations than outfield players during match-play [11-13], however no between-half declines in TD have been identified [11, 12] and no study has investigated whether goalkeepers experience more transient fluctuations in physical or technical performance. Notably, outfield players demonstrate short-term (i.e., 5-15 min) reductions in HIR, accelerations, and repeated sprint performance following intense periods of play [4-6, 53]. Despite the infrequency with which goalkeepers perform high-intensity actions [11, 13, 16, 25], it is plausible that fatigue or other situational influences (e.g., fatigue in outfield players) may affect transient changes in match responses in goalkeepers also. Therefore, research documenting the physical and technical performance of goalkeepers over shorter-term epochs (e.g., 5-15 min, rolling averages etc.) would provide a useful insight. Such investigations may be facilitated by development of goalkeeper-specific monitoring systems which are able to quantify the intensity, frequency, and duration of the explosive movements commonly performed. With the technological advances in this area, opportunities exist to establish validity and reliability, and to conduct in-depth analyses of goalkeepers' internal and external loads during both training and match-play. Of particular interest are the physiological responses to various goalkeeper-specific training practices, which differ dramatically from those of their outfield counterparts.

Despite the extensive research existing in relation to outfield players [for reviews see: 5, 18, 54-58], and palpable differences in match-demands [11-13], no studies have investigated the physiological or fatigue responses of soccer goalkeepers either within-game (e.g., acid-base balance, substrate depletion etc.) or post-match (e.g., biochemical or hormonal markers, performance capacity etc.). Established relationships between HIR performed during match-play and both Creatine kinase concentrations and neuromuscular performance at 24 h post-game [59], suggest that goalkeepers may experience a lesser degree of match-induced fatigue than their outfield counterparts. Nevertheless, goalkeepers perform a number of explosive jumps and high-velocity kicking actions during match-play, and a professional Dutch goalkeeper reported lower levels of self-reported 'wellness' on the day following a match, compared with most other days during the week [13]. Whilst it remains unclear whether this response is 'typical', given that subjective wellness is responsive to both acute and chronic training load, and associations between wellness changes and neuromuscular fatigue have been identified [60-62], such observations suggest additional fatigue is experienced following a match when compared to that incurred during training. Because self-reported wellbeing may encompass psychological state in addition to physical symptoms, it is possible that the mental fatigue incurred by soccer goalkeepers during match-play (empirical observations) may contribute to these findings. In addition, independent of the degree of physical loading, post-match wellness may be influenced by various situational factors such as opposition quality, match location, and the quality of opposition [63]. Future work should therefore investigate goalkeepers' physiological responses to particular activities within training and match-play to enable physical loads to be appropriately periodised. In addition. as exists for outfield players [2], development and validation of a goalkeeper-specific match-play simulation protocol would enable deeper insights and facilitate research without the degree of between-game variation inherent in soccer match-play [11, 17, 64]. Interestingly, as reported in outfield players [17, 64], greater variation has been observed for EPL goalkeepers' higher- versus lower-speed activities, with coefficients of variation ranging from 104.2% for sprinting, to 10.9% for walking and TD [11].

Isolated performance tests confirm the differing physiological profiles between goalkeepers and outfield players. Goalkeepers generate greater knee flexion and extension PT than the majority of outfield players [32, 34], and most studies involving senior goalkeepers report superior jump performance compared with their outfield counterparts [36, 41-43]. In assessments of linear and multidirectional speed, all studies except one [45] have reported some aspect of inferior performance for goalkeepers when compared to at least one other positional sub-group. Likewise, irrespective of playing standard, poorer multi-stage fitness test performance [38, 40, 44] and lower $\dot{V}O_{2max}$ [36, 37, 42, 43, 46, 48, 49] values have been consistently reported for goalkeepers relative to outfield players. These observations seem likely to reflect the lesser TD covered by goalkeepers in training and match-play [2-13, 26], and the only included study to report no difference in multi-stage fitness test performance between goalkeepers and other positions [39], involved under-18 players who may have received less exposure to position-specific training [39].

This review has summarised the available literature pertaining to the performance responses of soccer goalkeepers. Whilst the lack of methodological standardisation makes cross-study conclusions difficult to draw, this article attempts to reconcile the findings to date and highlight common observations with respect to goalkeepers' performance profile. In promoting an 'assess then address' approach, we have identified avenues for future research, particularly concerning the physiological responses to training and match-play; investigations which may complement existing performance data and highlight areas for improvement.

COMPLIANCE WITH ETHICAL STANDARDS

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LEGENDS

Table I: Records investigating the match performance of soccer goalkeepers
Table II: Records investigating the strength and power of soccer goalkeepers
Table III: Records investigating the linear and multidirectional speed of soccer goalkeepers
Table IV: Records examining the maximal aerobic capacity of soccer goalkeepers
Table V: Records investigating the soccer-skill performance of soccer goalkeepers
Table VI: Records investigating other aspects of performance in soccer goalkeepers

Table I: Records investigating the match performance of soccer goalkeepers

Study	Players	Data Collection	Variables	Results
De Baranda et al. 2008 [24]	International GKs (n = 34). Observed over 54 matches.	Systematic observation by four observers	Physical and technical GK actions (#·match^{-1}).	GKs performed 23.4±7.1 defensive technical actions·match^{-1}. Saves (9.96±3.8 #·match^{-1}) and foot control (6.5±4.2 #·match^{-1}) were the most frequent technical actions·match^{-1}. Most frequent physical action was displacement (18.87±6.0 #·match^{-1}); particularly moving forward (8.8±3.8 #·match^{-1})
Di Salvo et al. 2008 [11]	English Premier League GKs (n = 62). Observed over 102 matches.	Multiple camera tracking system.	TD and activity over various speed thresholds.	GKs covered 5611±613 m·match^{-1} including 56±34 m HSR (19.9-25.2 km·h^{-1}). ↔ for TD between halves. GKs performed 10±6 and 2±2 HS and SPR actions, respectively. Between-match CV% increased as speed of activity increased (walking CV%: 10.9; sprinting CV%: 104.2).
Soroka and Bergier 2011 [12]	International players (GK n unclear). Observed over 32 matches.	Multiple-camera tracking system.	TD.	GKs covered ↓ TD (4183±647 vs 9394±623 - 11036±695 m·match^{-1}) than OP, and covered 4 % ↑ TD in second-half (2133±391 m) than first-half (2049±293 m).
Clemente et al. 2013 [16]	International players (n = 35 GKs).	Official FIFA 2010 World Cup website: http://www.fifa.com/worldcup/archive/southafrica2010/index.html	TD (·min^{-1}), and % time in low-, medium-, high-intensity activity.	GKs covered ↓ TD (45.69±8.99 vs 109.94±6.04 m·min^{-1}) and spent ↑ time in low-intensity activity than OP (97.8 vs 82.9%).
Nassis 2013 [31]	International players (n = 105 GKs).	Data from official FIFA websites (http://www.fifa.com/worldcup/statistics/players/distanceandspeed.html, and www.fifa.com/worldcup/archive/southafrica2010/statistics/index.html).	Goals conceded due to GK error.	↔ for number of goals conceded due to GK error between sea level and altitudes >1400 m (0.4±0.6 vs 0.2±0.3 goals·match^{-1}).

Hongyou et al. 2015 [14]	Spanish La Liga GKs (n = 46). Observed over 744 full-matches.	Data provided by OPTA Sportsdata.	15 technical key performance indicators.	GKs on high-level teams performed ↓ BT, Passes, PtFH, Interceptions, Clearances, YC, BR, Saves, Catches and LB, but ↑ PA and AoPtFH than low-level teams. Opposition quality, match-outcome, and match-location influenced these relationships.
Padulo et al. 2015 [25]	Professional Italian players (n = 10 GKs). Observed over 10 matches.	Video time-motion analysis.	Frontal actions, lateral actions, high-intensity distance, and number of changes of direction.	GKs performed 52±24 forward actions (3.55±0.78 m) and 40±28 lateral actions (3.70±2.12 m). GKs covered 270±163 $m \cdot match^{-1}$ at HI. Higher level GKs (division C) covered 60% more HI distance than those one division below (385±21 vs 155±15 $m \cdot match^{-1,}$).
Malone et al. 2018 [13]	GK (n=1) from the tope league in the Netherlands. Observed over 43 weeks.	Wearable GPS and subjective wellness questionnaire.	TD, average speed, accelerations/decelerations, player load, and subjective wellness.	GK covered 5985±940 m on match-day (including warm-up), at average speed of 50±5 $m \cdot min^{-1}$. GK performed 11±5 accelerations and 5±3 declarations >3 $m \cdot s^{-2}$.

AoPtFH: Accuracy (% success) of pass made into the opponents half, BR: Ball recovered from opponent during open play, BT: Ball touches, CV%: Co-efficient of variation, GK(s): Goalkeeper(s), HI: High-intensity, HS: High speed , HSR: High-speed running, LB: Lost possession, n: Participant number, OP: Outfield players, PA: Pass accuracy (% of pass completion success), PtFH: Pass made into the opponents half, SPR: Sprint, TAU: Ratio of the distance between the shooter and GK, and GK's current velocity, TD: Total distance, TTC: Time to contact, YC: Yellow cards, ↑: Higher/increased, ↔: No difference, ↓: Lower/decreased.

Table II: Records investigating the strength and power of soccer goalkeepers

Study	Players	Data Collection methods.	Variables	Results
Arnason et al. 2004 [36]	Professional Icelandic players (n = 16 GKs).	Pre-season fitness profiling. LPT (squat), and jump mat.	Leg extensor power (smith machine back squat), CMJ, SL CMJ, and SJ height.	GKs produced ↑ leg extensor power (1451±233 vs 1309±185 – 1400±212 W) than OP. ↔ for CMJ (0.38 m) or SJ (0.36 m) height between GKs and OP.
Gil et al. 2007 [37]	Sub-elite Spanish players (n = 29 GKs).	In season fitness profiling. Jump mat.	SJ, CMJ, and 40 cm DJ height.	↔ for SJ (0.42 m), CMJ (0.42 m), or DJ (0.43 m) height between GKs and OP. ↔ for CMJ height (0.41 m) between selected and non-selected GKs.
Sporis et al. 2009 [43]	Professional Croatian players (n = 30 GKs).	Pre-season fitness profiling. Force platform.	SJ and CMJ height.	GKs had ↑ SJ (0.47±0.01 vs 0.42±0.04 – 0.44±0.03 m) and CMJ (0.49±0.02 vs 0.44 ±0.02 – 0.45±0.03 m) height than OP.
Boone et al. 2012 [42]	Professional Belgian players (n = 17 GKs).	Pre-season fitness profiling. Jump mat.	SJ and CMJ height.	GKs had ↑ SJ height (0.42±0.03 vs 0.39±0.03 and 0.39±0.03 m) and CMJ height (0.46±0.03 vs 0.41±0.04 and 0.41±0.04 m) than FB and MF.
Haugen et al. 2013 [41]	Professional, semi-professional, and amateur Norwegian players (n = 45 GKs).	Longitudinal fitness profiling (stage of season unclear). Force platform.	CMJ height.	GKs had ↑ CMJ height (0.40±0.02 vs 0.38±0.04 m) than MF. GK CMJ height positively correlated with 0-20 m (r = 0.55; 0.31 - 0.73) and 30-40 m (r = 0.61; 0.39 - 77) sprint velocities.
Rebelo et al. 2013 [44]	Elite and sub-elite U19 Portuguese players (n =18 GKs).	In season fitness profiling. Jump mat (SJ, CMJ), isokinetic dynamometry (PT).	SJ and CMJ height, and knee flexion and extension concentric PT at 90 $°\cdot s^{-1}$.	↔ for SJ height (0.41 m), CMJ height (0.42 m), knee flexion PT (117.0 Nm), or knee extension PT (236.0 Nm) between elite and sub-elite GKs.

Nikolaidis et al. 2014 [35]	Greek Division 2-5 players (n = 15 GKs).	In season fitness profiling. Hand dynamometer (grip strength), back dynamometer (trunk/leg strength), Infrared timing system (CMJ), and cycle ergometer.	Isometric grip, back, and back/leg strength, CMJ_A height, and PO during PWC_{170} cycle ergometer test, 5x7 s incremental cycle ergometer test, and Wingate test.	↔ for L (48.31 kg) or R (50.75 kg) hand grip, back (146.09 kg), or back/leg (174.00 kg) strength between GKs and OP. ↔ for CMJ_A height between GKs and OP (0.37 m). ↔ for absolute (218 W) or relative (2.70 W·kg^{-1}) PWC_{170} PO between GKs and OP. ↔ for absolute (1135 W) or relative (14.09 W·kg^{-1}) 5x7 s PO between GKs and OP. GKs had ↓ relative mean Wingate PO (8.2±0.7 vs 8.8±0.8 - 9.1±0.6 W·kg^{-1}) than OP, but ↔ for absolute mean PO (656 W), peak PO (888 W), or relative peak PO (11.0 W·kg^{-1}) between GKs and OP.
Deprez et al. 2015 [40]	Professional U19 Belgian players (n = 19-20 GKs).	In season fitness profiling. Infrared timing system.	SBJ distance and CMJ height.	↔ for SBJ distance (2.30 m) or CMJ height (0.38 m) between GKs and OP.
Rebelo-Gonçalves et al. 2015 [38]	Regional elite and sub-elite U19 Portuguese players (n = 33 GKs)	In season fitness profiling. Infrared timing System.	CMJ height.	↔ for CMJ height between GKs and OP (0.37 m).
Ruas et al. 2015 [32]	Professional Brazilian players (n = 12 GKs).	Pre-season strength profiling. Isokinetic dynamometry.	Concentric knee flexion and extension PT and eccentric knee flexion PT at 60°·s^{-1}.	GKs had ↑ concentric knee flexion and extension PT in the PL (flexion: 182.0±35.0 vs 150.0±26.0 – 159.0±34.0 Nm, extension: 302.0±34.0 vs 244.0±36.0 – 266.0±27.0 Nm) and NPL (flexion: 162.0±31.0 vs 148.0±40.0 – 163.0±31.0 Nm) than all OP except CB. ↔ for eccentric knee flexion PT between GKs and OP for PL (247.0 Nm) or NPL (211.0 Nm).
Bona et al. 2017 [34]	Provincial U17 Brazilian players (n = 2 GKs).	Pre-season fitness profiling. Isokinetic dynamometry.	Concentric knee flexion and extension PT at 60 and 300 °·s-^{1}.	↑ knee flexion and extension PT in the NPL in GKs (flexion: 143.0±10.9, extension: 280.0±14.0 Nm) than FB (flexion: 117.5±11.5, extension: 236.0±14.8 Nm), DM (flexion: 121.4±16.1, extension: 237.1±43.3 Nm), MF (flexion: 96.6±9.2, extension: 195.0±21.8 Nm), and F (flexion: 120.5±32.2, extension: 236.1±53.6 Nm) at 60 °·s-^{1}.

				↔ for flexion (141.9 Nm) or extension (281.3 Nm) PT in the PL between GKs and OP at 60 °·s-1. GKs had ↑ flexion and extension PT in the PL (flexion 92.3±20.4 vs 78.4±10.9, 87.6±8.5, 67.4±10.2, and 85.6±13.0 Nm, extension: 130.3±8.2 vs 119.0±14.5, 119.3±11.2, 100.2±10.8, and 124.9±11.3 Nm) and NPL (flexion 94.2±20.9 vs 76.9±9.4, 86.2±14.7, 61.7±6.2, and 84.3±16.8 Nm, extension: 127.1±6.9 vs 117.4±16.1, 123.4±14.0, 95.4±6.4, and 125.0±16.9 Nm) than FB, DM, MF, and F at 300 °·s-1.
Towlson et al. 2017 [39]	Professional U18 English players (n = 10 GKs).	In season fitness profiling. Jump mat.	CMJ height.	↔ for CMJ height between GKs and OP (0.31 m).

BM: Body mass, CB: Centre backs, CMJ: Countermovement jump, CMJ_A: CMJ with arm swing permitted, DJ: Drop jump, F: Forwards, FB: Fullbacks, GKs: Goalkeepers, L: left, LPT: Linear position transducer, MF: Midfielders, n: Participant number, NPL: Non-preferred limb, OP: Outfield players, PL: Preferred limb, PO: Power output, PT: Peak torque, PWC_{170}: Power work-capacity at 170 beats·min^{-1} test (2x3 min cycle ergometer test against incremental external load), R: Right, SBJ: Standing broad jump, SJ: Squat jump, U: Under, ↑: Higher/increased , ↔: No difference, ↓: Lower/decreased.

Table III: Records investigating the linear and multidirectional speed of soccer goalkeepers

Study	Players	Data Collection methods	Variables	Results
Taşkin 2008 [45]	Professional Turkish players (n = 42 GKs).	In season skill assessment. Electronic timing gates (linear sprint) and handheld stopwatch (four-line test).	30 m sprint and four-line test times.	↔ for 30 m sprint (4.26 s) or four-line (14.19 s) time between GKs and OP.
Gil et al. 2007 [37]	Sub-elite Spanish players (n = 29 GKs).	In season fitness profiling. Electronic timing gates.	30 m sprint (flying start) and 30 m slalom time.	GKs had ↑ 30 m sprint (3.83 vs 3.51 s) and 30 m slalom (4.97 vs 4.56 s) times than F. ↔ for 30 m sprint (3.86 s) or 30 m slalom (5.06 s) times between selected and non-selected GKs.
Aziz et al. 2008 [46]	Professional Singapore players (n = 16 GKs).	Pre-season fitness profiling. Electronic timing gates.	6 x 20 m rRSA (FST and TST).	GKs had ↑ TST than OP (26.00±0.91 vs 25.39±0.90 s). ↔ for FST between GKs and OP (3.12 s).
Sporis et al. 2009 [43]	Professional Croatian players (n = 30 GKs).	Pre-season fitness profiling. Electronic timing gates	5 m, 10 m, and 20 m sprint times.	GKs had ↑ 10 m (2.35±0.80 vs 2.03±0.90 - 2.23±0.50 s) and 20 m (3.51±0.90 vs 3.28±0.70 - 3.43±0.80 s) sprint times than OP. ↔ for 5 m sprint time between GKs and OP (1.45 s).
Kaplan 2010 [47]	Amateur Turkish players (n = 9 GKs).	In season fitness profiling. Electronic timing gates.	7 x 34.2 m rRSA incorporating slalom (time for each sprint, FST, MST).	↔ for MST (7.72s), FST (7.49 s), fatigue index (0.48 s), or time to complete any of sprints 1-7 between GKs and OP. ↔for time to complete any of sprints 1-7 for GKs (7.67-7.72 s).
Boone et al. 2012 [42]	Professional Belgian players (n = 17 GKs).	Pre-season fitness profiling. Electronic timing gates.	10 m sprint (0-5 m, and 5-10 m time), and 5 x 10 m sprint time.	GKs had ↑ 0-5 m and 5-10 m times (1.46±0.07 and 0.76±0.06 s vs 1.43±0.04 and 0.72±0.04 s, respectively) than F. GKs had ↑ 5 x 10 m times (12.32±0.44 vs 12.01±0.25 and 12.09±30 s, respectively) than F and MF.

Haugen et al. 2013 [41]	Professional, semi-professional, and amateur Norwegian players (n = 58 GKs).	Longitudinal fitness profiling (stage of season unclear). Electronic timing gates.	40 m sprint (0-10 m, 10-20 m, 20-30 m, and 30- 40 m split times).	GKs covered 0-10 m in 1.55±0.06 s, 10-20 m in 1.27±0.05 s, 20-30 m in 1.18±0.04 s, and 30-40 m in 1.17±0.05 s. GKs had ↓ 0-20 m velocity (7.10 vs 7.35 and 7.23 $m{\cdot}s^{-1}$, respectively) than F and DF.
Rebelo et al. 2013 [44]	Elite and sub-elite U19 Portuguese players (n =18 GKs).	In season fitness profiling. Electronic timing gates.	30 m sprint (5 m and 30 m times) and T-test time.	↔ for 5 m (1.03 s), 30 m (4.31s), or T-test (9.02 s) times between elite and sub-elite GKs
Deprez et al. 2015 [40]	Professional U19 Belgian players (n = 16-20 GKs).	In season fitness profiling. Electronic timing gates (sprints) and handheld stopwatch (T-test).	4 x 30 m rRSA (fastest 0-5 m and 30 m time), and T-test time.	GKs had ↑ 30 m sprint time (4.44±0.15 vs 4.28±0.14 s) than F. ↔ for 5 m time (1.08 s) between GKs and OP. ↔ for T-test time (left: 8.52 s, right: 8.61 s) between GKs and OP.
Rebelo-Gonçalves et al. 2015 [38]	Regional elite and sub-elite U19 Portuguese players (n = 33 GKs).	In season fitness profiling. Electronic timing gates.	7 x 30 m rRSA (including slalom) TST, and 10 x 5 m shuttle TST.	↔ for rRSA TST between GKs and OP (54.66 s). GKs had ↑ 10 x 5 m shuttle TST (18.62±0.94 vs18.21±0.67 s) than OP.
Towlson et al. 2017 [39]	Professional U18 English players (n = 10 GKs).	In season fitness profiling. Electronic timing gates.	20 m sprint (10 m and 20 m times) and T-test time	GKs had ↑ 10 m [1.65 (1.61–1.67) vs 1.60 (1.58–1.63) s] and 20 m [2.94 (2.88–2.99) vs 2.84 (2.80–2.87) s] sprint time than WM only. ↔ for T-test time between GKs and OP (9.33 s).

DF: Defenders, F: Forwards, FST: Fastest sprint time, GK: Goalkeepers, MF: Midfielders, MST: Mean sprint time, n: Participant number, OP: Outfield players, rRSA: Running repeated sprint ability test, TST: Total sprint time, U: Under, WM: Wide midfielders, ↑: Higher/increased, ↔: No difference, ↓: Lower/decreased.

Table IV: Records examining the maximal aerobic capacity of soccer goalkeepers

Study	Players	Data Collection	Variables	Results
Arnason et al. 2004 [36]	Professional Icelandic players (n = 15 GKs)	Pre-season fitness profiling. Inspired/expired gas during incremental treadmill test.	$\dot{V}O_{2max}$.	GKs had ↓ $\dot{V}O_{2max}$ relative to BM (57.3±4.7 vs 62.8±4.4 – 63.0±4.4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) than OP.
Tahara et al. 2006 [49]	High school U18 Japanese players (n = 6 GKs).	Fitness profiling (stage of season unclear). Inspired/expired gas during incremental treadmill test.	$\dot{V}O_{2max}$.	GKs had ↓ $\dot{V}O_{2max}$ relative to BM (54.2±4.5 vs 61.4±5.3 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) than OP, but ↔ for absolute $\dot{V}O_{2max}$ (3.87 $L{\cdot}min^{-1}$) between GKs and OP.
Gil et al. 2007 [37]	Sub-elite Spanish players (n = 29 GKs).	In season fitness profiling. Estimated from Astrand cycle ergometer test.	$\dot{V}O_{2max}$.	GKs had ↓ absolute $\dot{V}O_{2max}$ (3.63±0.92 vs 4.13±0.97 - 4.37±1.09 $L{\cdot}min^{-1}$) and $\dot{V}O_{2max}$ relative to BM (48.4±11.1 vs 57.7±9.9 - 62.4±10.7 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) than OP. ↔ in $\dot{V}O_{2max}$ relative to BM (48.4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) between selected and non-selected GKs.
Aziz et al. 2008 [46]	Professional Singaporian players (n = 16 GKs).	Pre-season fitness profiling. Estimated from beep test.	$\dot{V}O_{2max}$.	GKs had ↓ $\dot{V}O_{2max}$ relative to BM (50.2±5.3 vs 54.3±3.4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) than OP.
Sporis et al. 2009 [43]	Professional Croatian players (n = 30 GKs).	Pre-season fitness profiling. Inspired/expired gas during incremental treadmill test.	$\dot{V}O_{2max}$, HR_{max}, maximal running speed, and BLa upon completion.	GKs had ↓ $\dot{V}O_{2max}$ relative to BM (50.5±2.7 vs 58.9±2.1 - 62.3±3.1 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) and BLa upon completion (9.3±3.1 vs 10.5±3.1 - 13.3±1.9 $mmol{\cdot}L^{-1}$) than OP. ↔ for HR_{max} (189 $beats{\cdot}min^{-1}$) or maximal running speed (15.4 $km{\cdot}h^{-1}$) between GKs and OP.
Boone et al. 2012 [42]	Professional Belgian players (n = 17 GKs).	Pre-season fitness profiling. Inspired/expired gas during incremental treadmill test.	$\dot{V}O_{2max}$, and LT.	GKs had ↓ $\dot{V}O_{2max}$ relative to BM (52.1±5.0 vs 55.6±3.5 - 61.2±2.7 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) and ↓ LT (12.7±1.4 vs 13.4±0.6 – 14.4±0.7 $km{\cdot}h^{-1}$) than OP.

Rebelo et al. 2013 [44]	Elite and sub-elite U19 Portuguese players (n =18 GKs).	In season fitness profiling. Yo-Yo IR2 test.	TD.	↔ for TD between elite and sub-elite GKs (992 m).
Deprez et al. 2015 [40]	Professional U19 Belgian players (n = 8 GKs).	In season fitness profiling. Yo-Yo IR1 test.	TD.	GKs covered ↓ TD (1575±213 vs 2316±540 - 2353±391 m) than OP.
Rebelo-Gonçalves et al. 2015 [38]	Regional elite and sub-elite U19 Portuguese players (n = 33 GKs)	In season fitness profiling. Beep test.	TD.	GKs covered ↓ TD (1519±424 vs 1777±620 m) than OP.
Towlson et al. 2017 [39]	Professional U18 English players (n = 10 GKs).	In season fitness profiling. Beep test.	TD.	↔ for TD between GKs and OP (2223 m).
Marcos et al. 2018 [48]	Professional Cypriot players (n = 18 GKs).	Pre-season fitness profiling. Inspired/expired gas during incremental treadmill test.	$\dot{V}O_{2max}$.	GKs had ↓ $\dot{V}O_{2max}$ relative to BM (51.5±5.7 vs 56.1±6.3 and 56.5±6.9 $ml \cdot kg^{-1} \cdot min^{-1}$) than MF and WG only.

BM: Body mass, BLa: Blood lactate concentration, GKs: Goalkeepers, HR_{max}: Maximum heart rate, LT: Lactate threshold, MF: Midfielders, n: Participant number, OP: Outfield players, TD: Total distance, U: Under, WG: Wingers, ↑: Higher/increased, ↔: No difference, ↓: Lower/decreased.

Table V: Records investigating the soccer-skill performance of soccer goalkeepers

Study	Players	Data Collection methods	Variables	Results
Taşkin 2008 [45]	Professional Turkish players (n = 42 GKs).	In season skill assessment. Handheld stopwatch.	Dribbling speed (time to complete)	GKs took ↑time to complete (21.14±0.58 vs 20.52±0.38 - 20.69±0.59 s) than OP.
Erkmen 2009 [52]	Professional Turkish players (n = 47 GKs).	In season skill assessment. Subjectively scored 0-6.	Heading accuracy (score when received from in front, and from the right).	GKs scored ↓ than F (6.94±3.38 vs 9.41±3.31 AU) when receiving from in front. GKs scored ↓than DF and F (4.32±3.15 vs 6.13±3.45 and 8.53±3.48 AU) When receiving from the right,
Rebelo et al. 2013 [44]	Elite and sub-elite U19 Portuguese players (n =18 GKs).	In season fitness profiling. Electronic timing gates (dribbling speed).	Ball control (# touches) and dribbling speed (time to complete).	↔ for ball control (106 touches) or dribbling speed (16.89 s) between elite and sub-elite GKs.
Deprez et al. 2015 [40]	Professional U19 Belgian players (n = 17 GKs).	In season fitness profiling. Handheld stopwatch.	UGent dribbling test time to complete.	GKs took ↑ time (20.52 ± 2.06 vs 17.77±1.19 - 18.27±1.32 s) than OP.
Rebelo-Gonçalves et al. 2015 [38]	Regional elite and sub-elite U19 Portuguese players (n = 33 GKs)	In season fitness profiling. Observer counting (touches, passes), observer scoring (shooting accuracy), and hand-held stopwatch (dribbling speed).	Ball control (# touches), short passing (# passes in 20 s), shooting accuracy (# points), and dribbling speed (time to complete).	↔ for ball control (149 touches) between GKs and OP. GKs completed ↓ passes (12±3 vs 24±2 passes) and had ↑ dribbling time (12.96±0.88 vs 12.41±0.69 s) than OP. GKs had ↑ shooting accuracy (23±3 vs 10±3 points) than OP

AU: Arbitrary units, DF: Defenders, F: Forwards, GK: Goalkeepers, n: Participant number, OP: Outfield players, U: Under, ↑: Higher/increased, ↔: No difference ↓: Lower/decreased.

Table VI: Records investigating other aspects of performance in soccer goalkeepers

Study	Players	Data Collection	Variables	Results
Arnason et al. 2004 [36]	Professional Icelandic players (n = 24 GKs).	Pre-season fitness profiling. Photograph analysis and goniometry.	Hamstrings, adductors, rectus femoris, and hip flexors ROM.	GKs had ↑ Hip flexor (181.4±6.5 vs 178.5±5.8 - 179.0±5.1°) and rectus femoris (138.5±8.0 vs 134.0±7.1 - 134.7±7.3°) ROM than OP.
Nikolaidis et al. 2014 [35]	Greek Division 2-5 players (n = 15 GKs).	In season fitness profiling. SAR test.	ROM.	↔ for SAR ROM (25.7 cm) between GKs and OP.
Deprez et al. 2015 [40]	Professional U19 Belgian players (n = 16-20 GKs).	In season fitness profiling. SAR test, and KTK test.	ROM, and gross motor coordination.	↔ for SAR ROM (27.4 cm) between GKs and OP. ↔ for motor coordination (72 AU) between GKs and OP.

AU: Arbitrary units, GK: Goalkeepers, KTK: Körperkoordination Test für Kinder, n: Participant number, OP: Outfield players, ROM: Range of motion, SAR: Sit and reach, U: Under, ↑: Higher/increased, ↔: No difference, ↓: Lower/decreased.