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Original Article

Goalkeeper horizontal accelerations and decelerations during soccer training: varying exercises could be the best option

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Abstract
The demands placed on goalkeepers are often neglected in scientific research. This study seeks to evaluate the acceleration and deceleration requirements across various exercise categories: 'Complementary' (tailored training for goalkeepers separated from team drills), 'Integrated' (team-based drills not position-specific), and 'Specific' (exercises targeting position-specific tactical, technical, and physical skills). Data were collected from 52 observations during nineteen training sessions across three highly trained goalkeepers from a Portuguese U23 team. Acceleration and deceleration demands were retrieved through GPS 10 Hz technology, including the effort starting speed (< 5 km·h^{-1}, 5-10 km·h^{-1}, 10-15 km·h^{-1}, 15-20 km·h^{-1}, 20-25 km·h^{-1} and > 25 km·h^{-1}). Efforts intensities were classified relatively and individually (low: 25-50%; moderate: 50-75%; high: > 75%). Mean ± SD were calculated to the number of efforts per minute, one-way analysis of variance (ANOVA) assessed potential differences between the players and t-test assessed differences between exercise' categories. No differences between players were found regarding acceleration (p=0.918) or deceleration (p=0.685) efforts. 'Integrated' category elicited less low-intensity accelerations and decelerations than 'Complementary' and 'Specific' categories (p<.05); and 'Specific' category elicited more moderate-intensity decelerations than 'Integrated' (p<.01) and 'Complementary' (p<.05). Goalkeeping is a singular position in soccer requiring different exercise categories to provide different resources to players: from simulating match demands, such as the 'integrated' exercises with outfield players, to improving goalkeepers' capabilities with 'specific' and 'complementary' exercises. Due to the uniqueness of the position, practitioners should consider varying training exercises of goalkeepers to provide different acceleration and deceleration stimuli.
Key Words: **football, global positioning system, speed, training load**

Introduction

The goalkeeper (GK) in soccer is a unique playing position with very specialized and complex demands (Malone et al., 2018; Otte et al., 2022). Because the GK is the only player allowed to play the ball with hands, inside the own area, the GK's abilities to stop opponent goal opportunities can have a huge impact on the match score and provide distinctive possibilities for teams in possession of the ball (Perez-Arroniz et al., 2022). Specifically, in terms of actions, GKs frequently are exposed to shots, high crosses, and one-on-one situations (West, 2018) which alternate with long periods of no direct involvement in the match (White et al., 2018). Additionally, previous research on competition has found that based on teams' and individual players' tactical and contextual preferences, GK often play a role in the offensive part of the match (White et al., 2018). Indeed, currently, more offensive actions, such as passing the ball, have been registered in comparison with defensive actions (Obetko et al., 2022; Perez-Arroniz et al., 2022). Subsequently, the quality of offensive actions (e.g., receive passes, ability to pass forward, and distribute the ball well) can distinguish elite from sub-elite GKs, and may be justified by the different playing styles and the evolving playing philosophy (Serrano et al., 2019). In this regard, a ball possession approach may require a more proficient participation of the GK in the offensive phase of the match and that capability can impact the success of the team (Serrano et al., 2019).

The match performance of the GK has been highlighted in the literature, reporting a technical evolution leading to fewer actions overall, with higher quality executions, and with the prevalence of offensive actions in

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matches (Obetko et al., 2022; Perez-Arroniz et al., 2022). To transfer this knowledge to GK-specific training, a previous study (Jara et al., 2018) reported more defensive and offensive actions in smaller formats of sided matches. However, since software to assess technical actions is usually not available in training sessions, research often focuses on monitoring physiological GK demands in training and matches. Inversely to what happens during technical actions, physical demands of the GK appear to be consistent over time (Serrano et al., 2019), with this position covering shorter distances than any other playing position (Perez-Arroniz et al., 2022; West, 2018), and usually underreach as many high-intensity efforts as outfielders (Otte et al., 2022).

However, the intense efforts that occur for the GK during matches appear to be abrupt and may often end up being critical actions, especially sprints between 0 and 5 meters (Salvo et al., 2008). Considering these short distances and the abrupt characteristic of the intense efforts (Kubayi, 2020), analysis of acceleration (ACC) and deceleration (DEC) have become particularly important to GK performance (West, 2018).

For various reasons, ACC and DEC performances and GK' efforts may vary between training and matches, and equivalent or higher efforts than matches may be reported during the middle of the week training sessions (Malone et al., 2018; Moreno-Pérez et al., 2020; White et al., 2018, 2020). For example, higher ACC and DEC demands were reported in small sided-games in comparison with larger formats (Jara et al., 2019). Besides ACC and DEC, GK can also be required to perform high-speed displacements to cover a wide field area, to compensate a potential placement of the defenders near the midfielders (Altavilla, 2023).

Generally, GK-specific training aims to replicate match demands and is composed of technical and complex/game-representative parts that should include a holistic training approach (i.e., coupling perception of match-relevant information, decision-making tasks, and the physical coordination of GK actions) (Otte et al., 2020). To the best of our knowledge, no study to date has investigated the different physical demands of GK specific training exercises. This examination has already been done on outfield positions, showing higher demands in sided games than circuit training (Giménez et al., 2020) or continuous and shuttle running drills (Castagna et al., 2017). These results could be of paramount importance for strength and conditioning coaches as well as GK coaches, in order to evaluate and optimize training programs. We hypothesize that GK will face higher demands during specific and complementary exercises, due to the similarity of integrated exercises with matches, where GK do not interact with the ball as frequently as outfield players.

Therefore, the purpose of this study is to compare ACC and DEC demands of different exercise categories of GK training in one soccer mesocycle and apply this knowledge to training sessions design.

Materials & methods

Participants

Three highly trained (Tier 3) GK with an average age of 18.3 ± 1.5 years, an average height of 187.0 ± 4.4 cm and an average weight of 78.0 ± 8.0 kg participated in this study. A priori power analysis was conducted with G-Power 3.1 software, indicating 45 observations (Lakens, 2022) to achieve a power of 0.95. GPS unit data from 19 training sessions were collected, resulting in 52 observations. Ethics Committee clearance was obtained (35/2021) and the study was conducted in accordance with the Declaration of Helsinki. Written consent was obtained by the club.

Procedures

Using a retrospective observational approach, GKs' training demands were determined during training sessions of an U23 team competing in Revelation League (Portuguese U23 League) during the 2020/21 season. The team completed a total of 19 sessions and four matches during the analyzed mesocycle. Notably, during the matches 2 GKs played for the team, but one of them usually trained with the first team squad. As so, match data was excluded from this analysis. The entire training mesocycle was completed on a natural grass surface.

Training exercises were divided in different categories, previously established by the coaching staff, and without any interference or adaptation for research purposes:

1) *Complementary* (i.e., exercises that address specific goalkeeper needs, in a more individualized approach, specific to the GK(s) that were not integrated during a team drill);

2) *Integrated* (i.e., exercises with no GK-specific content, where outfield players participated with higher technical/tactical objectives, such as offensive organization exercises, small-sided games with GK, or shooting drills); and finally,

3) *Specific* (i.e., exercises that focused on the development of technical, tactical, and physical capabilities specifically related to the position, such as shooting and crossing drills, distribution drills, positioning, and feet orientation depending on ball position drills).

GPS devices were used (Catapult G7; Catapult Sports, Melbourne, Australia) with sampling frequencies of 10 Hz, which have shown a good level of accuracy to assess running patterns in soccer (Scott et al., 2016). The GPS unit was placed on the upper middle back between the scapulae of the subject using special protective vests as recommended by the manufacturer. This equipment is a certified FIFA Electronic Performance and Tracking System. The variables used to record the external demands were the number of accelerations (ACC)

and decelerations (DEC) and the time in each exercise for the relative count (number of efforts per minute). Each effort was counted from the start of the velocity increase or decrease until the change in velocity reached 0 $m \cdot s^{-2}$ (Silva, Nakamura, Ribeiro, et al., 2023). ACC and DEC intensities were classified with the percentage intensity (low-intensity: 25-50%; moderate-intensity: 50-75%; high-intensity: > 75%) in reference to the maximal effort achieved by each player and according to the respective starting speed interval (Silva, Nakamura, Serpiello, et al., 2023), a method that adapted the Sonderegger and colleagues' proposal (Sonderegger et al., 2016). To retrieve the maximal effort, we collected the higher ACC and DEC value of the mesocycle of each player, excluding isolated values. For example, if the maximal ACC value was 7.30 $m \cdot s^{-2}$, another value between 7-8 $m \cdot s^{-2}$ had to exist for this value to be considered maximal. Additionally, the starting speed of each ACC and DEC was also collected according to bandwidth intervals: (< 5 $km \cdot h^{-1}$, 5-10 $km \cdot h^{-1}$, 10-15 $km \cdot h^{-1}$, 15-20 $km \cdot h^{-1}$, 20-25 $km \cdot h^{-1}$ and > 25 $km \cdot h^{-1}$) (Silva, Nakamura, Serpiello, et al., 2023).

Statistical Analysis

Three statistical approaches were used, all conducted with jamovi (Jamovi, n.d.). First, mean ± SD were calculated for ACC and DEC efforts, considering intensity intervals (low-intensity: 25-50%; moderate-intensity: 50-75%; high-intensity: > 75%) and starting speed intervals (< 5 $km \cdot h^{-1}$, 5-10 $km \cdot h^{-1}$, 10-15 $km \cdot h^{-1}$, 15-20 $km \cdot h^{-1}$, 20-25 $km \cdot h^{-1}$ and > 25 $km \cdot h^{-1}$). Second, a one-way analysis of variance (ANOVA) was conducted to assess potential differences between the players (players as grouping variable and number of efforts as dependent variable). Statistical significance was established at $p<.05$.

And finally, paired samples t-tests with 95% confidence intervals (CI) were conducted to assess differences between exercises categories, within the different intensity intervals and the different starting speeds intervals, regarding ACC and DEC efforts. For example, the number of high-intensity ACC per minute registered during the 'Complementary' category was compared with the number of high-intensity ACC per minute registered during the 'Integrated' category. Effect sizes (ES) with 95% CI were calculated as Cohen's d and interpreted as trivial (<0.2), small (0.2<0.6), moderate (0.6<1.2), large (1.2<2.0), very large (2.0<4.0) and huge (>4.0) with 95% confidence intervals (Hopkins et al., 2009). If the CI crossed both positive and negative values, an unclear effect size was established ($p>.05$) (Batterham & Hopkins, 2006).

Results

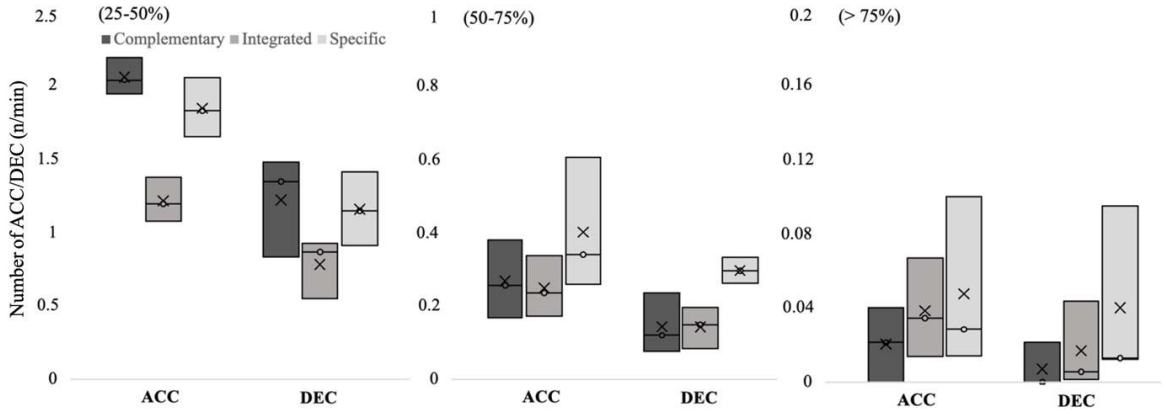

Figure 1. Number of accelerations and decelerations per minute (Mean ± SD) for each exercise category and for each intensity interval (25-50%, 50-75% and > 75%). ACC=acceleration; DEC=deceleration.

Means ± SD of ACC and DEC registered during the different exercises categories are presented in Figure 1, according to the intensity interval. Similarly, Figure 2 presents the means ± SD of ACC and DEC registered during the different exercises categories, according to the starting speed interval.

No differences between the players were found regarding ACC (p=0.918) or DEC (p=0.685) efforts. However, differences between exercises categories were found and are presented in Table 1 (intensity intervals) and in Table 2 (starting speed intervals). Effect sizes (with 95% CI) of the differences (for intensity and starting speed intervals) are represented in Figure 3.

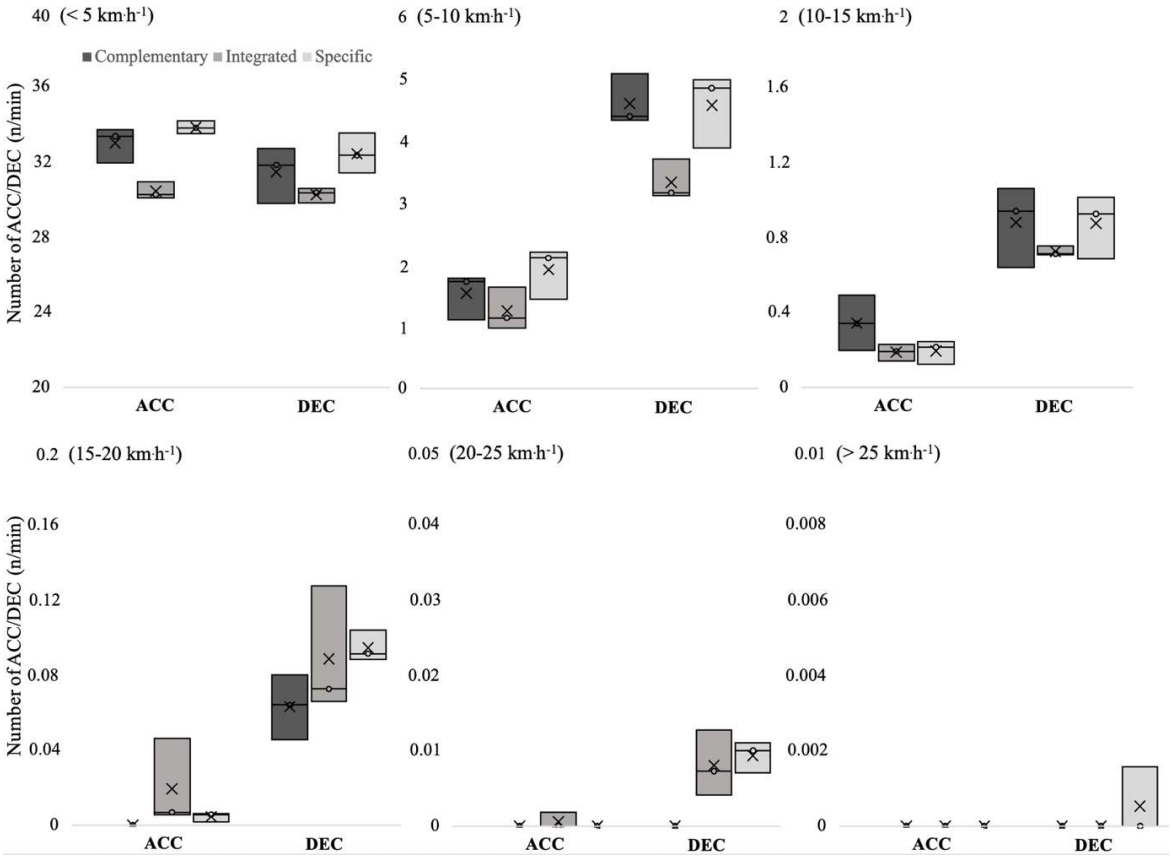

Figure. 2. Number of accelerations and decelerations per minute (Mean ± SD) according to the starting speed (< 5 km·h^{-1}, 5-10 km·h^{-1}, 10-15 km·h^{-1}, 15-20 km·h^{-1}, 20-25 km·h^{-1} and > 25 km·h^{-1}) of each effort that occurred in each training exercise category. ACC=acceleration; DEC=deceleration.

Table 1. Mean Differences (95% CI) and Effect Size (Cohen's *d*) with 95% CI between accelerations and decelerations per minute of the different training exercises categories (Complementary, Integrated and Specific) and for each intensity interval 25-50%, 50-75% and > 75%).

	Acceleration		**Deceleration**	
Complementary	*Integrated*	*Specific*	*Integrated*	*Specific*
25-50%	-1.01 [-1.74, -0.29]*	-0.26 [-0.86, 0.35]	-0.53 [-0.94, -0.11]*	-0.08 [-0.49, 0.33]
	ES: -3.50 [-6.87, -0.26]	ES: -1.06 [-2.48, 0.48]	ES: -3.16 [-6.25, -0.18]	ES: -0.46 [-1.62, 0.79]
50-75%	-0.02 [-0.08, 0.04]	0.13 [-0.07, 0.33]	-0.00 [-0.16, 0.16]	0.15 [0.00, 0.31]*
	ES: -0.82 [-2.11, 0.60]	ES: 1.67 [-0.25, 3.52]	ES: -0.01 [-1.14, 1.12]	ES: 2.49 [0.00, 5.00]
>75%	0.02 [-0.00, 0.04]	0.03 [-0.04, 0.10]	0.01 [-0.02, 0.04]	0.03 [-0.05, 0.12]
	ES: 2.31 [-0.05, 4.67]	ES: 0.94 [-0.54, 2.30]	ES: 0.89 [-0.56, 2.23]	ES: 0.94 [-0.54, 2.29]
Integrated				
25-50%	-	0.76 [0.30, 1.22]*	-	0.45 [0.14, 0.77]*
		ES: 4.08 [0.39, 7.97]		ES: 3.59 [0.28, 7.05]
50-75%	-	0.15 [-0.10, 0.40]	-	0.15 [0.10, 0.21]**
		ES: 1.53 [-0.30, 3.27]		ES: 7.44 [1.04, 14.36]
>75%	-	0.01 [-0.04, 0.06]	-	0.02 [-0.04, 0.08]
		ES: 0.43 [-0.81, 1.59]		ES: 0.94 [-0.53, 2.31]

Note: * p<.05, **p<.01, ***p<.001. Negative differences or effect sizes favors the category in the first column.

Table 2. Mean Differences (95% CI) and Effect Size (Cohen's *d*) (95% CI) between accelerations and decelerations per minute starting speeds of the different training exercises categories (Complementary, Integrated and Specific) and for each starting speed threshold (0-5 km·h^{-1}, 5-10 km·h^{-1}, 10-15 km·h^{-1}, 15-20 km·h^{-1} and 20-25 km·h^{-1}).

	Acceleration		**Deceleration**	
Complementary	*Integrated*	*Specific*	*Integrated*	*Specific*
0-5 km·h^{-1}	-2.59 [-6.01, 0.83] ES: -1.88 [-3.89, 0.18]	0.83 [-1.80, 3.45] ES: 0.78 [-0.61, 2.06]	-1.21 [-5.52, 3.09] ES: -0.70 [-1.94, 0.65]	0.98 [-2.74, 4.70] ES: 0.65 [-0.68, 1.88]
5-10 km·h^{-1}	-0.29 [-1.04, 0.47] ES: -0.95 [-2.31, 0.53]	0.38 [0.17, 0.58]* ES: 4.56 [0.49, 8.89]	-1.27 [-1.53, -1.01]** ES: -11.98 [-22.28, -1.82]	-0.03 [-1.37, 1.31] ES: -0.06 [-1.18, 1.08]
10-15 km·h^{-1}	-0.16 [-0.41, 0.10] ES: -1.51 [-3.24, 0.31]	-0.15 [-0.37, 0.07] ES: -1.66 [-3.50, 0.25]	-0.16 [-0.65, 0.34] ES: -0.79 [-2.07, 0.61]	-0.00 [-0.12, 0.12] ES: -0.09 [-1.22, 1.05]
15-20 km·h^{-1}	-	-	0.03 [-0.02, 0.08] ES: 1.28 [-0.39, 2.85]	0.03 [-0.03, 0.09] ES: 1.30 [-0.39, 2.87]
20-25 km·h^{-1}	-	-	-	-
> 25 km·h^{-1}	-	-	-	-
Integrated				
0-5 km·h^{-1}	-	3.42 [1.84, 5.00]* ES: 5.37 [0.65, 10.41]	-	2.20 [0.04, 4.35]* ES: 2.54 [0.01, 5.08]
5-10 km·h^{-1}	-	0.66 [0.01, 1.32]* ES: 2.53 [0.01, 5.07]	-	1.24 [-0.19, 2.67] ES: 2.15 [-0.10, 4.38]
10-15 km·h^{-1}	-	0.01 [-0.04, 0.06] ES: 0.29 [-0.90, 1.42]	-	0.15 [-0.22, 0.52] ES: 1.01 [-0.51, 2.40]
15-20 km·h^{-1}	-	-0.02 [-0.07, 0.04] ES: -0.67 [-1.90, 0.67]	-	0.01 [-0.09, 0.10] ES: 0.16 [-1.00, 1.28]
20-25 km·h^{-1}	-	-	-	0.00 [-0.01, 0.01] ES: 0.37 [-0.85, 1.52]
> 25 km·h^{-1}	-	-	-	-

Note: * p<.05, **p<.01, ***p<.001. Note: * p<.05, **p<.01, ***p<.001. Negative differences or effect sizes favors the category in the first column.

Discussion

The aim of the present study was to compare acceleration (ACC) and deceleration (DEC) demands of different exercise' categories in soccer GK training during a mesocycle. Our main finding highlights that lower ACC and DEC intensities occur more frequently than higher intensities, regardless of the exercise' category. Concerning the novel comparison between exercise categories for soccer GKs (i.e., here divided into 'Complementary', 'Integrated', and 'Specific'), as hypothesized, 'Specific' exercises elicited higher demands than 'Complementary' and 'Integrated' exercises. In the following, results are discussed from an integrated perspective, applying empirical findings to practical soccer (goalkeeping) coaching.

Generally, GK training sessions greatly differ from sessions of their outfield playing teammates. While it is well known that the soccer GK position encompasses unique match demands (Otte et al., 2022), specific training exercises – that promote the ability to catch, deflect and punch the ball under different contexts and constraints – are important and appear to elicit higher physical demands than during competitive matches (White et al., 2020). In addition, GKs need specific stimuli during training to develop physical (as well as tactical-technical) capabilities to perform particular actions such as dives, jumps or quick reactions (White et al., 2020). Interestingly, during matches, GKs can go by without significant physical and mental effort but with high technical participation if their team is able to dominate the opposition (Kubayi, 2020; Serrano et al., 2019). All these factors should be accounted for when developing exercises and managing physical intensities for goalkeeping training.

In the present study we identified that less than 1 high-intensity (> 75%) ACC or DEC occurred per minute in each of the three different training exercise categories (i.e., 'Complementary', 'Integrated', and 'Specific'). This is in line with previous research that stated that high-intensity ACC and DEC occur less frequently during training sessions than low- or moderate-intensity efforts (Silva et al., 2022). When comparing high-intensity efforts (> 75%), we found unclear effect sizes between the exercises' categories (Table 1). However, 'Specific' exercises elicited more moderate-intensity DEC than 'Complementary' (very large effect sizes) and 'Integrated' (huge effect sizes) (Figure 3). Although comparisons with previous studies are difficult, as research comparing exercise categories is scarce, one previous study reported higher intensity actions (including explosive efforts) in GK activities, that could be interpreted as 'Specific' compared to small-sided games (i.e., a form of 'Integrated', according to our differentiation) (White et al., 2020). The differences between both studies can potentially be explained by the different intensity classification approaches (Silva, Nakamura, Serpiello, et al., 2023). We assessed the training demands with individual and relative thresholds, avoiding arbitrary and absolute thresholds.

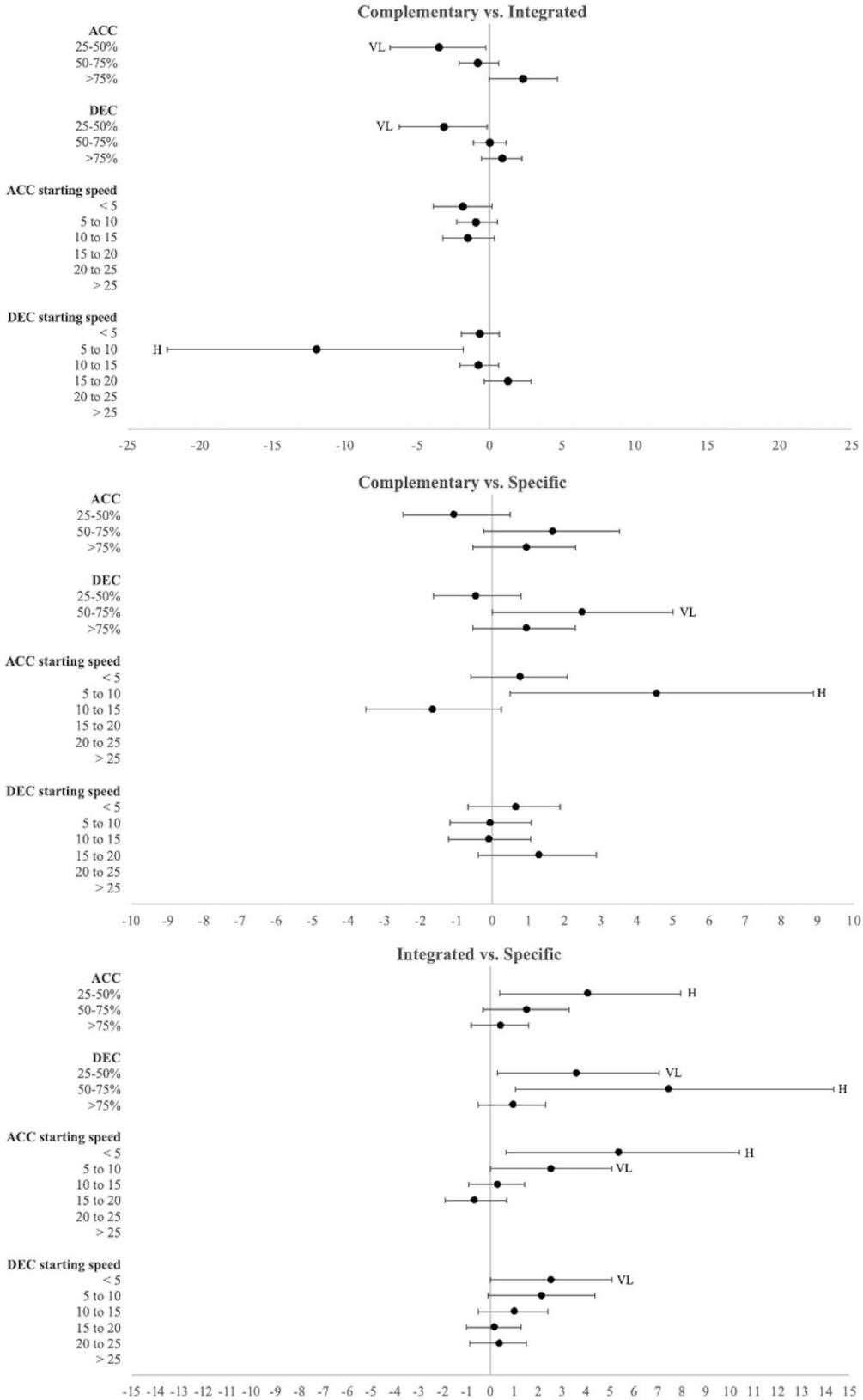

Figure. 3. Effect sizes (with 95% CI) from the mean differences between different exercise categories for accelerations and decelerations per minute according to the respective intensity percentage interval, and to the respective starting speed ($km \cdot h^{-1}$) interval. ACC=acceleration; DEC=deceleration. H huge effect size; VL very large effect size.

We also presented a novel approach by identifying the efforts starting speed. This innovation provides an interesting insight for GK training analysis. For instance, during 'Integrated' exercises, GKs are expected to be in their position and quickly react to a specific situation, such as rushing from the goal to intercept a ball. In our study, during 'Integrated' training exercises, GKs were exposed to more efforts from starting speeds > 15 $km \cdot h^{-1}$ than during 'Complementary' exercises (Figure 2). Although no clear effect size was reported regarding these differences, this analysis presents a new perspective to be explored. Since GKs spend almost the entire match (96%) standing or walking/jogging (Szwarc et al., 2019), 'Integrated' exercises can provide similar match context for the position in a very specific context, since the area covered from GKs has been increasing over the years (Altavilla, 2023). This is important because (match-)representative learning design and increased problem-solving activities for players within match-realistic environments are proven to be beneficial for player development (Woods et al., 2019). 'Specific' exercises, however, may methodically intend to develop GK capabilities, so high loads would be expected. This approach is in line with periodization, where players need to develop their readiness to perform (Mujika et al., 2018), while matches could fail to provide a sufficient physical stimulus to GKs (White et al., 2020).

Despite some previous efforts to investigate the GK position, to date, this playing position is scarcely examined in comparison with outfield players in soccer. However, based on previous research into positional differences (Gil et al., 2014), it appears only logic that the GK position requires different (match-realistic) training approaches and physical stimuli/loadings compared to outfield positions (Otte et al., 2022). Overall, more research into the GK position is needed and this study aimed to help bridge this gap. For example, one could adapt the type of exercise and physical efforts with how the team is expected to perform in a match. If one team is expected to dominate the opponent, this team's GK would be exposed to fewer high-intensity ACC and DEC demands by being rarely exposed to defensive actions but could perform more efforts starting from higher starting speeds (i.e., the ball is expected to be away from GK which could provide more space to run). In contrast, if the team is expected to be dominated by opposition, the ball would be closer to the GK, exposing him to more intense and short actions.

Finally, different limitations exist as to the interpretation of data in this study. Our findings relate to a specific sample (i.e., three male GKs playing in Portugal's U23 league) and to a particular coaching staff that designs exercises in their specific way. Hence, generalizing exercise categorization represents a difficulty in this type of research as different staff in different countries/leagues/organizations use different strategies and training methodologies. Consequently, even if differences registered during performances in different professional leagues were minimal (Obetko et al., 2022) future studies with higher sample sizes are necessary. This is a specific challenge because teams count with less GKs than outfield players.

Therefore, merging exercises categories from different teams could provide a higher number of observations, while challenging different coaching staff to agree in exercises' categories. Furthermore, this study is limited to the measurement of horizontal displacements (i.e., ACC and DEC), while different specific GK actions, such as dives and jumps, were not considered and certainly place physical demands on GK. However, since that analysis is more frequent in scientific literature, and goalkeeping in soccer is not separated from the sport's particularities, such as performance, fatigue and injuries, this study aims to contribute to a gap in the literature and to practice considerations. For instance, our findings complement previous research that assessed the load imposed to GKs during jumps, and dives (Izzo et al., 2019). As so, practitioners should thoroughly periodize training interventions and carefully monitor their players to ensure that the desired development is being achieved and that fatigue and injury risk is as low as possible. Finally, while considering the absolute number of efforts could present higher occurrences, training sessions should be assessed relatively, as the duration of the exercises can impact the reported load.

Overall, this study showed that goalkeepers perform very few high-intensity (> 75%) accelerations and decelerations, and very few efforts starting at speeds > 15 $km \cdot h^{-1}$, regardless of the category of the training exercise. However, differences between training exercises were identified: 'Specific' exercises (i.e., exercises that focused on the development of technical, tactical, and physical capabilities specifically related to the position, such as shooting and crossing drills, distribution drills, positioning, and feet orientation depending on ball position drills) elicited higher acceleration and deceleration demands than 'Complementary' exercises (i.e., exercises that address specific goalkeeper needs, in a more individualized approach, specific to the GK(s) that were not integrated during a team drill) and 'Integrated' exercises (i.e., exercises with no GK-specific content, where outfield players participated with higher technical/tactical objectives, such as offensive organization exercises, small-sided games with GK, or shooting drills). Considering that the different exercises provide different acceleration and deceleration stimulus (such as different efforts' starting speed), varying exercises during goalkeepers' training can be the best strategy to apply during training sessions, considering the characteristics of the demands apply to this playing position demands.

Conclusions

This study demonstrated that different GK' exercises elicit different acceleration (ACC) and deceleration (DEC) demands. Although performing few high-intensity efforts (ACC and DEC), and few efforts starting at elevated speeds, this position needs to be monitored as outfield positions. Regarding the exercises categories comparisons, the 'Specific' exercises, that aim the development of GK capabilities, elicit higher demands than 'Integrated' and 'Complementary' exercises. Considering the uniqueness of the GK position, practitioners should consider varying training exercises to provide different acceleration and deceleration stimuli. Additionally, coaches should evaluate objectives prior to planning training sessions for all positions, including the GKs. Since competition can impose different demands according to the own team's playing style and opposition characteristics, coaches should prepare their players for what they intend. Periodization of physical efforts, such as position-specific acceleration and deceleration plays a critical role. Each exercise category provided a different stimulus to the GKs, including the 'Integrated' category which can provide similar match situations regarding efforts starting speeds. As so, variability between exercises can provide different, but critical, stimuli.

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Of note:

During data collection, Catarina Bajanca was Sports Scientist at Estoril Praia. During data analysis and interpretation and at the time of writing Catarina Bajanca is Sports Scientist at Sport Lisboa e Benfica.

References

Altavilla, G. (2023). Analysis and comparison of the goalkeeper's role in past and modern soccer: a pilot study. *Journal of Physical Education and Sport*, *23*(3), 564–568. https://doi.org/10.7752/jpes.2023.03070

Batterham, A. M., & Hopkins, W. G. (2006). Making Meaningful Inferences About Magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57.

Castagna, C., Francini, L., Póvoas, S. C. A., & D'Ottavio, S. (2017). Long Sprint Abilities in Soccer: Ball versus Running Drills. *International Journal of Sports Physiology and Performance*, *12*(9), 1256–1263. https://doi.org/10.1123/ijspp.2016-0565

Gil, S. M., Zabala-Lili, J., Bidaurrazaga-Letona, I., Aduna, B., Lekue, J. A., Santos-Concejero, J., & Granados, C. (2014). Talent identification and selection process of outfield players and goalkeepers in a professional soccer club. *Journal of Sports Sciences*, *32*(20), 1931–1939. https://doi.org/10.1080/02640414.2014.964290

Giménez, J. V., Jiménez-Linares, A. S., Gómez, M. A., Jiménez-Linares, L., Leicht, A. S., & Gómez, M. A. (2020). Predictive modelling of the physical demands during training and competition in professional soccer players. *Journal of Science and Medicine in Sport*, *23*(6), 603–608. https://doi.org/10.1016/j.jsams.2019.12.008

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Izzo, R., Giovannelli, M., & Raiola, G. (2019). Training load in elite goalkeepers with k-track for monitoring performance. *Journal of Physical Education and Sport*, *19*(5), 1890–1896. https://doi.org/10.7752/jpes.2019.s5280

Jamovi. (n.d.). *the jamovi project* (2.2). https://www.jamovi.org

Jara, D., Ortega, E., Gómez, M. Á., & Baranda, P. S. De. (2018). Effect of Pitch Size on Technical-Tactical Actions of the Goalkeeper in Small-Sided Games. *Journal of Human Kinetics*, *62*(1), 157–166. https://doi.org/10.1515/hukin-2017-0167

Jara, D., Ortega, E., Gómez-Ruano, M. Á., Weigelt, M., Nikolic, B., & de Baranda, P. S. (2019). Physical and tactical demands of the goalkeeper in football in different small-sided games. *Sensors*, *19*(16), 1–13. https://doi.org/10.3390/s19163605

Kubayi, A. (2020). Analysis of goalkeepers' game performances at the 2016 European Football Championships. *South African Journal of Sports Medicine*, *32*(1), 1–4. https://doi.org/10.17159/2078-516x/2020/v32i1a8283

Lakens, D. (2022). Sample Size Justification. *Collabra: Psychology*, *8*(1), 1–31. https://doi.org/10.1525/collabra.33267

Malone, J. J., Jaspers, A., Helsen, W. F., Merks, B., Frencken, W. G. P., & Brink, M. S. (2018). Seasonal Training Load and Wellness Monitoring in a Professional Soccer Goalkeeper. *International Journal of Sports Physiology and Performance*, *13*(5), 672–675.

Moreno-Pérez, V., Malone, S., Sala-Pérez, L., Lapuente-Sagarra, M., Campos-Vazquez, M. A., & del Coso, J. (2020). Activity monitoring in professional soccer goalkeepers during training and match play. *International Journal of Performance Analysis in Sport*, *20*(1), 19–30. https://doi.org/10.1080/24748668.2019.1699386

Mujika, I., Halson, S., Burke, L. M., Balagué, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International Journal of Sports Physiology and Performance*, *13*(5), 538–561. https://doi.org/10.1123/ijspp.2018-0093

Obetko, M., Peráček, P., Mikulič, M., & Babic, M. (2022). Technical–tactical profile of an elite soccer goalkeeper. *Journal of Physical Education and Sport*, *22*(1), 38–46. https://doi.org/10.7752/jpes.2022.01005

Otte, F., Dittmer, T., & West, J. (2022). Goalkeeping in Modern Football: Current Positional Demands and Research Insights. *International Sport Coaching Journal*, *10*(1), 112–120. https://doi.org/10.1123/iscj.2022-0012

Otte, F. W., Millar, S. K., & Klatt, S. (2020). How does the modern football goalkeeper train?–An exploration of expert goalkeeper coaches' skill training approaches. *Journal of Sports Sciences*, *38*(11–12), 1465–1473. https://doi.org/10.1080/02640414.2019.1643202

Perez-Arroniz, M., Calleja-González, J., Zabala-Lili, J., & Zubillaga, A. (2022). The soccer goalkeeper profile: bibliographic review. *Physician and Sportsmedicine*, *00*(00), 1–10. https://doi.org/10.1080/00913847.2022.2040889

Salvo, V. D. I., Benito, P. J., Salvo, M. D. I., & Pigozzi, F. (2008). Activity profile of elite goalkeepers during football match-play. *Journal of Sports Medicine and Physical Fitness*, *48*(4), 443–446.

Scott, M., Scott, T. J., & Kelly, V. G. (2016). The validity and reliability of global positioning systems in team sport: a brief review. *The Journal of Strength & Conditioning Research*, *30*(5), 1470–1490. https://doi.org/10.1519/JSC.0000000000001221

Serrano, C., Paredes-Hernández, V., Sánchez-Sánchez, J., Gallardo-Pérez, J., Da Silva, R., Porcel, D., Colino, E., García-Unanue, J., & Gallardo, L. (2019). The team's influence on physical and technical demands of elite goalkeepers in LaLiga: a longitudinal study in professional soccer. *Research in Sports Medicine*, *27*(4), 424–438. https://doi.org/10.1080/15438627.2018.1555755

Silva, H., Nakamura, F. Y., Beato, M., & Marcelino, R. (2022). Acceleration and deceleration demands during training sessions in football: a systematic review. *Science and Medicine in Football*. https://doi.org/10.1080/24733938.2022.2090600

Silva, H., Nakamura, F. Y., Ribeiro, J., Asian-Clemente, J., Roriz, P., & Marcelino, R. (2023). Using minimum e ff ort duration can compromise the analysis of acceleration and deceleration demands in football. *International Journal of Performance Analysis in Sport*, 1–13. https://doi.org/10.1080/24748668.2023.2201745

Silva, H., Nakamura, F. Y., Serpiello, F. R., Ribeiro, J., Roriz, P., & Marcelino, R. (2023). Preprint Adapting the percentage intensity method to assess accelerations and decelerations in football training : moving beyond absolute and arbitrary thresholds. *SportRxiv*. https://doi.org/10.51224/SRXIV.286

Sonderegger, K., Tschopp, M., & Taube, W. (2016). The challenge of evaluating the intensity of short actions in soccer: A new methodological approach using percentage acceleration. *PLoS ONE*, *11*(11), 1–10. https://doi.org/10.1371/journal.pone.0166534

Szwarc, A., Jaszczur-Nowicki, J., Aschenbrenner, P., Zasada, M., Padulo, J., & Lipinska, P. (2019). Motion analysis of elite Polish soccer goalkeepers throughout a season. *Biology of Sport*, *36*(4), 357–363. https://doi.org/10.5114/biolsport.2019.88758

West, J. (2018). A review of the key demands for a football goalkeeper. *International Journal of Sports Science and Coaching*, *13*(6), 1215–1222. https://doi.org/10.1177/1747954118787493

White, A., Hills, S. P., Cooke, C. B., Batten, T., Kilduff, L. P., Cook, C. J., Roberts, C., & Russell, M. (2018). Match-Play and Performance Test Responses of Soccer Goalkeepers: A Review of Current Literature. *Sports Medicine*, *48*(11), 2497–2516. https://doi.org/10.1007/s40279-018-0977-2

White, A., Hills, S. P., Hobbs, M., Cooke, C. B., Kilduff, L. P., Cook, C., Roberts, C., & Russell, M. (2020). The physical demands of professional soccer goalkeepers throughout a week-long competitive microcycle and transiently throughout match-play. *Journal of Sports Science*, *38*(8), 848–854.

Woods, C. T., McKeown, I., Shuttleworth, R. J., Davids, K., & Robertson, S. (2019). Training programme designs in professional team sport: An ecological dynamics exemplar. *Human Movement Science*, *66*, 318–326. https://doi.org/10.1016/j.humov.2019.05.015