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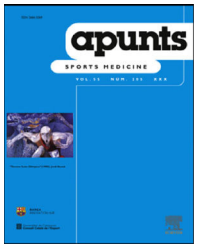

SPECIAL ARTICLE

Comparing the most demanding scenarios of official matches across five different professional team sports in the same club

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KEYWORDS
Team sports;
Match demands;
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Local positioning system

Abstract
Introduction: The purpose of this study was to compare the most demanding scenarios (MDS) of match-play across five different team sports of the same club (basketball, futsal, handball, rink hockey and soccer) during five different time epochs (30, 60, 120, 180 and 300 s).
Material and methods: Sixty-five professional male players were monitored across 14 to 17 official matches via a local positioning system. Peak physical demands included total distance, distance, and actions >18 km·h^{-1} and distance and number of accelerations and decelerations >2 m·s^{-2}. One-way analysis of variance and Tukey post-hoc tests were used to test statistical significance ($p < .05$), whereas standardized Cohen's effect size and the respective 95% confidence intervals were calculated to detect differences between team sports.
Results: While soccer and rink hockey achieved the greatest MDS in total distance, and distance and number of actions >18 km·h^{-1} during all the time epochs examined, basketball presented the highest peak values in number of accelerations and decelerations >2 m·s^{-2} during 30-s and 60-s time epochs.
Conclusion: In conclusion, the MDS during competition are significantly different across team sports, which can be useful in determining the upper limit threshold for sport-specific training optimisation and return to play purposes.

Introduction

Monitoring professional players' physical demands during competition has long been a subject of great interest for

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sport scientists and practitioners from a wide range of multi-directional outdoor and indoor team sports.[1,2] The nature of each sport determines the physical requirements and the crucial player movement patterns that define the activity profile for each specific sport discipline. Therefore, coaches and rehabilitation specialists therefore face the challenge of designing and developing sport-specific and position-specific individual and team-based training programs together with rehabilitation and return-to-play protocols.[1]

Global (GPS) and local positioning systems (LPS), which are based on ultra-wide band technology and include inertial devices, have been a game-changer in the sport performance analysis process. This can provide team sport practitioners with a more in-depth understanding of the physical and technical demands of sports activities, coupled with a useful and objective method for planning, assessing and quantifying physical demands in addition to a real-time analysis of players' on-field performance during training and competition.[3] Even through many existing studies have quantified average physical demands in different team-sports using variables such as distance, high-speed running and high-intensity accelerations and decelerations in different team-sports,[4–7] the authors are not aware of any investigation comparing different sports examined using the same methodology.

Although average values have been traditionally been used for physical demand assessment, recent research has suggested that this approach may underestimate the most demanding scenarios (MDS) of match-play[8,9] due to the intermittent and fluctuating nature of both field and indoor team sports.[8] For instance, studies in soccer [9] and rugby union [10] have reported up to 25% higher values when using rolling average techniques to measure the MDS in high-speed running compared to segmental analysis approaches. Consequently, training program prescription based on average physical demands during competition may result in players being underprepared for the MDS of match play.[8]

In addition to the comparison between analysis techniques, a growing body of literature has recognized the significance of the identification and quantification of the MDS during competition in different team sports, such as soccer,[11] basketball[12,13] and rink hockey.[14] One common procedure among researchers has consisted of investigating the MDS using different time epochs ranging from 30 seconds to 10 minutes, obtaining similar outcomes with higher relative demands when the time window was shorter.[11–14] When designing training drills and rehabilitation protocols based on the MDS of match play, it is worth considering that extrapolations of the peak values from a particular epoch length to longer or shorter training drills may fail to prepare players for what they will encounter during competition.[12]

Although GPS and LPS provide researchers and practitioners with quantitative data from a diversity of physical demand variables, specific metrics may be more applicable to some team sports than others due to the inherent nature of each sport. To establish specific team sports requirements and allow sport professionals to optimise the training process, the main purpose of this study was to compare the MDS of match-play across five different team sports (basketball, futsal, handball, rink hockey and soccer) during five different time epochs (30, 60, 120, 180 and 300 s).

Material and methods

Experimental approach to the problem

A retrospective observational design was used to examine the differences between the MDS of official matches across five different team sports. Positional data were collected from a total of 76 league matches (basketball = 17; futsal = 15; handball = 14; rink hockey = 15; and soccer = 15) for two consecutive seasons (2018-2019 and 2019-2020). Goalkeepers and players who did not play a minimum total time of 10 min were excluded from the analysis, resulting in a total of 3901 individual observations.

Participants

The 65 male players (mean ± SD, age: 24.83 ± 5.42 years; height: 186.24 ± 12.91 cm; and body mass: 81.42 ± 14.65 kg) that participated in this study belonged to five different team sports of the same Spanish club (Table 1) and competed at a professional level. This study, in which all players agreed to participate voluntarily by giving their written consent, fulfilled the recommendations of the Declaration of Helsinki.[15] No ethics committee approval was needed after players were routinely monitored in all official matches and training sessions during the competitive season.[16]

Procedures

Table 2 shows the main official rules of the five different professional team sports examined. All official matches were completed on the same official sport-specific indoor court or outdoor field in similar environmental conditions. More particularly, all teams were monitored during the home matches of their national competition, which were usually played during in-season weekends, after a standard 45-min warm-up consisting of dynamic mobility and individual sport-specific skills such as passing, dribbling, and shooting. Although players were continuously monitored during warm-ups and total match time, the MDS were only analysed when players were competing on court, excluding when they were resting after substitutions and inactivity time between periods. Players were allowed to drink water ad libitum during recovery periods. Furthermore, all five teams followed the specific structured training methodology during each microcycle, consisting of coadjuvant and optimising training.[17]

Match data were recorded using a LPS (WIMU PRO™ RealTrack Systems S.L., Almería, Spain). The inertial devices were placed in a custom-made vest located in the centre of the upper back using an adjustable harness (IMAX, Lleida, Spain), in accordance with the manufacturer's recommendations. For optimal signal emission and reception, the LPS includes six ultra-wideband antennas placed in a hexagon.[18] It is important to note that WIMU PRO™ has been shown to deliver good/acceptable accuracy and inter- and intra-unit reliability for ultra-wide band positioning.[19] Data were downloaded and analysed using the system-specific software (SPRO™, version 959, RealTrack Systems, Almería, Spain).

Similar to available research in indoor and outdoor team sports,[1,20] a total of seven variables were examined. Total distance covered and distance covered >18 km·h^{-1} (in meters) and number of actions >18 km·h^{-1} were measured

Table 1 Anthropometry results, playing positions and league name of the five different professional team sports.

Sport	N	Age (y)	Height (cm)	Body mass (kg)	Playing positions	Competitive league
Basketball	11	20.1 ± 1.5	199.8 ± 8.7	91.7 ± 16.5	CE = 2 FO = 3 GU = 6	LEB Oro
Futsal	14	28.6 ± 2.5	176.7 ± 6.2	73.7 ± 6.0	BM=4 PV=2 WI=8	Liga Nacional de Futbol Sala
Handball	16	28.5 ± 4.5	198.3 ± 11.7	96.2 ± 12.9	BA = 6 CB = 2 LP = 2 WI = 6	Liga Asobal
Rink hockey	8	29.5 ± 6.2	180.8 ± 4.2	78.9 ± 5.5	EX = 6 IN=2	OK Liga
Soccer	16	20.9 ± 1.0	179.4 ± 7.5	71.9 ± 8.7	CB = 4 FB = 3 FW = 3 MF = 6	2ª División B de Futbol

Note: CE is centers; FO is forwards; GU is guards; BM is backman; PV is pivots; WI is wingers; BA is backs; CB is center back; LP is line player; WI is wings; EX is exteriors; IN is interiors; FB is fullback; FW is forward, and MF is midfielder.

via positional differentiation (change in location with each signal), whereas distance (in meters) and number of accelerations and decelerations >2 m·s^{-2} were calculated via double differentiation from the positional data recorded by LPS.[3] In line with previous investigations,[12,18] the analysis of the MDS consisted of identifying the maximum values of the physical demand parameters of interest using a rolling average technique over five different time epochs (30, 60, 120, 180 and 300 s), previously used in multiple studies measuring the most demanding passages of match-play in different team sports.[20] It is important to note that the peak values for each physical demand parameter were recorded independently for each player, meaning that they probably came from different data points.

Statistical analysis

Descriptive data from official matches were reported as mean ± standard deviation (SD). While the dependent variables were the seven physical exertion indicators, there was one independent variable: sports (basketball, futsal, handball, rink hockey and soccer). All data analyses were performed using the RStudio software version 1.2.5033 (RStudio, Inc.). The normality and homogeneity of variances were tested using Levene's tests. One-way analysis of variance (ANOVA) with partial eta squared analysis to find the effect size of the ANOVA was used to test differences between sports. The statistical significance was set at $p < 0.05$. Tukey HSD post-hoc tests were conducted for each pairwise comparison. Furthermore, Cohen's d effect size (ES) was computed with 1,000 times bootstrapped 95% confidence intervals (95% CI). Thresholds for effect size statistics were <0.20, negligible; 0.20 - 0.49, small; 0.50 - 0.8, medium; >0.8, large.[21]

Results

The descriptive results of the MDS for all team sports and time epochs are presented in Table 3. Soccer and rink hockey show the greatest values in total distance covered, distance and number of actions >18 km·h^{-1} and distance at acceleration and deceleration >2 m·s^{-2}. Conversely, basketball, futsal and rink hockey show the largest peak values in

Table 2 Main official rules for the professional team sports examined.

	Basketball	Futsal	Handball	Rink hockey	Soccer
Playing area (m)	Indoor 28 × 15	Indoor 40 × 20	Indoor 40 × 20	Indoor 40 × 20 (With fences)	Outdoor 100 × 80
Field players (n)	5	4	6	4	10
Duration (min)	4 × 10	2 × 20	2 × 30	2 × 25	2 × 45
Time-outs (n)	10	4	6	8	No
Clock	Stopped	Stopped	Continuous	Stopped	Continuous
Substitutions	Unlimited when the clock is stopped	Unlimited when the clock is stopped	Unlimited with clock running	Unlimited with clock running	Three per team

Table 3 Descriptive results, means (± SD) in selected physical demands for the professional team sports and time epochs.

	Dist (m)	Dist >18km·h^{-1} (m)	Dist >18km·h^{-1} (n)	Acc >2m·s^{-2} (m)	Dec >2m·s^{-2} (m)	Acc >2m·s^{-2} (n)	Dec >2m·s^{-2} (n)
30 s Time epoch							
Basketball	82.8 ± 8.2	19.8 ± 6.7	2.4 ± 0.8	34.6 ± 5.7	31.5 ± 5.7	7.1 ± 1.3	6.7 ± 1.3
Futsal	92.3 ± 8.1	25.4 ± 8.2	2.3 ± 0.7	37.6 ± 6.8	33.8 ± 6.2	6.8 ± 1.2	6.7 ± 1.2
Handball	87.3 ± 14.6	30.3 ± 14.9	2.4 ± 0.9	32.9 ± 8.6	29.8 ± 9.7	4.7 ± 1.0	4.1 ± 1.0
Rink Hockey	128.0 ± 9.6	60.5 ± 14.3	4.1 ± 0.8	50.7 ± 7.1	50.1 ± 8.2	6.9 ± 1.0	6.4 ± 0.8
Soccer	135.2 ± 46.3	63.8 ± 25.5	10.3 ± 3.7	52.5 ± 14.1	33.4 ± 12.9	5.5 ± 1.1	5.4 ± 1.1
60 s Time epoch							
Basketball	138.4 ± 11.8	23.0 ± 7.2	2.9 ± 0.9	48.4 ± 8.0	42.7 ± 8.3	10.3 ± 2.2	9.6 ± 2.3
Futsal	152.5 ± 13.5	29.3 ± 9.8	2.9 ± 0.9	50.7 ± 8.9	46.1 ± 8.2	9.7 ± 2.0	9.4 ± 1.9
Handball	133.2 ± 19.7	37.9 ± 20.0	3.0 ± 1.1	43.4 ± 10.6	37.4 ± 12.5	6.4 ± 1.5	5.5 ± 1.4
Rink Hockey	221.0 ± 12.7	76.4 ± 16.3	5.3 ± 1.1	71.9 ± 9.0	68.9 ± 10.7	10.3 ± 1.4	9.5 ± 1.4
Soccer	212.4 ± 68.7	72.8 ± 27.9	12.1 ± 4.5	66.2 ± 16.0	40.8 ± 13.1	7.4 ± 1.4	7.1 ± 1.4
120 s Time epoch							
Basketball	235.1 ± 34.9	27.2 ± 8.9	3.6 ± 1.2	68.3 ± 12.6	59.5 ± 12.6	15.1 ± 4.1	14.2 ± 3.8
Futsal	262.3 ± 21.6	36.2 ± 13.6	3.6 ± 1.3	74.7 ± 14.6	66.2 ± 11.8	14.5 ± 3.0	14.1 ± 3.0
Handball	217.8 ± 32.1	47.8 ± 26.7	3.9 ± 1.6	60.6 ± 15.4	50.7 ± 18.5	9.2 ± 2.1	7.7 ± 1.9
Rink Hockey	390.4 ± 25.4	101.3 ± 22.4	7.4 ± 1.5	107.7 ± 15.2	100.9 ± 15.1	15.9 ± 2.2	14.7 ± 2.3
Soccer	345.1 ± 95.0	87.3 ± 32.5	15.2 ± 5.4	89.9 ± 19.9	54.1 ± 15.5	10.5 ± 2.0	10.2 ± 2.1
180 s Time epoch							
Basketball	316.2 ± 28.1	31.5 ± 10.7	4.2 ± 1.3	85.1 ± 16.7	73.7 ± 16.1	19.5 ± 5.5	18.1 ± 5.3
Futsal	363.9 ± 29.1	41.1 ± 15.9	4.2 ± 1.5	96.1 ± 19.1	83.0 ± 15.4	18.8 ± 3.8	18.3 ± 3.9
Handball	306.8 ± 57.4	58.5 ± 35.5	5.0 ± 2.3	77.5 ± 21.9	62.5 ± 23.8	11.8 ± 2.8	9.7 ± 2.8
Rink Hockey	552.5 ± 37.0	122.1 ± 26.0	9.1 ± 1.8	139.3 ± 20.2	128.6 ± 20.3	20.9 ± 3.1	19.2 ± 3.3
Soccer	465.0 ± 97.3	104.8 ± 36.3	18.0 ± 6.4	113.8 ± 26.2	68.1 ± 17.9	13.7 ± 3.2	13.3 ± 3.2
300 s Time epoch							
Basketball	456.1 ± 62.9	38.0 ± 14.5	5.1 ± 1.8	113.7 ± 26.5	96.4 ± 23.8	26.6 ± 8.4	24.3 ± 7.8
Futsal	556.6 ± 45.3	49.6 ± 21.2	5.2 ± 1.9	131.8 ± 27.0	113.8 ± 22.3	26.3 ± 5.1	25.2 ± 5.4
Handball	450.4 ± 72.0	74.7 ± 47.5	6.2 ± 2.9	102.8 ± 28.9	80.6 ± 30.7	16.0 ± 3.7	13.0 ± 3.5
Rink Hockey	845.2 ± 63.6	158.8 ± 35.4	12.1 ± 2.5	198.8 ± 33.1	181.7 ± 29.7	30.0 ± 4.7	27.3 ± 4.9
Soccer	647.7 ± 188.8	123.9 ± 45.7	21.9 ± 8.7	143.3 ± 43.0	83.9 ± 26.6	17.2 ± 5.4	16.8 ± 5.4

Note: Dist is distance, Acc is accelerations, and Dec is deceleration.

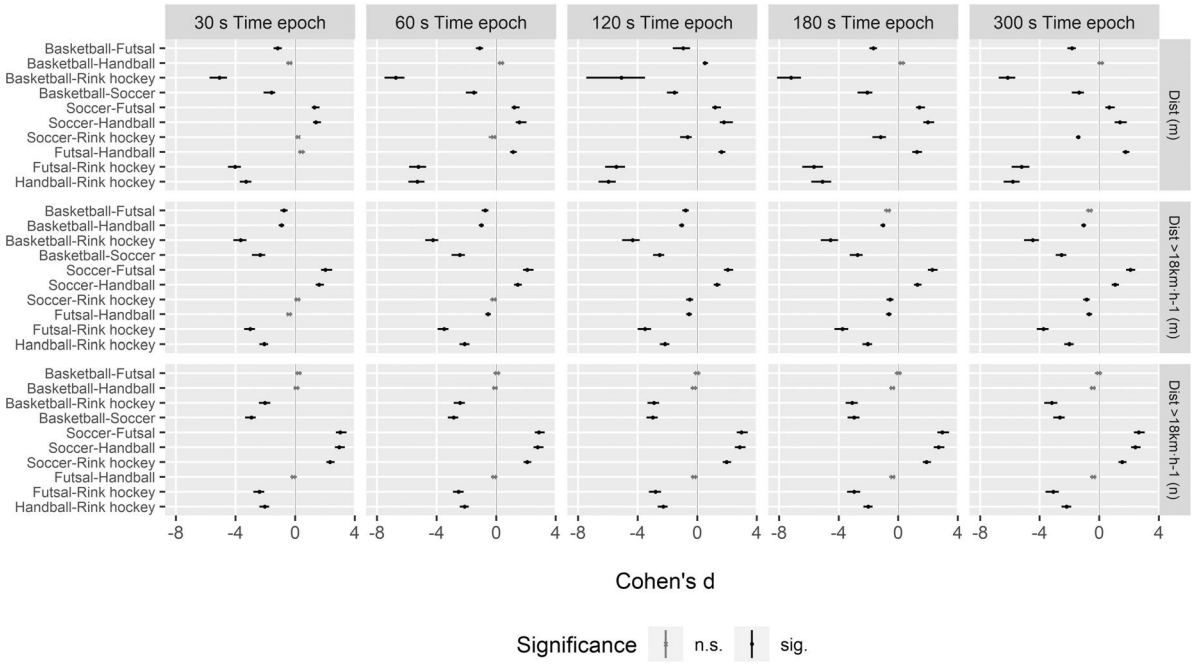

Fig. 1 Post-hoc, effect size analysis (Cohen's d) and it's 95% CI between the professional team sports for the distance related variables. Note: The black lines indicate significant differences ($p < 0.05$) between team sports, whereas the grey lines indicate non-significant differences ($p > 0.05$). Dist (m) is distance.

number of accelerations and decelerations >2 m·s^{-2}. Furthermore, the ANOVA results for all time epochs and variables show that there are significant differences with large or very large effect sizes in all cases ($p < 0.01$ in all tests).

Post-hoc and effect size analysis for pairwise comparisons between sports are shown in Figs. 1 and 2. Soccer and rink hockey present the greatest values in distance covered and distance covered >18 km·h^{-1} in meters ($p < 0.05$; ES > 0.8; Large) compared to all other sports in all time epochs; soccer achieves the highest results in distance covered >18 km·h^{-1} and number of times >18 km·h^{-1} ($p < 0.05$; ES > 0.8; Large); except in the 30-s time epoch, rink hockey show the greatest results in distance at acceleration >2 m·s^{-2} ($p < 0.05$; ES > 0.8; Large) and the highest values in distance at deceleration >2 m·s^{-2} ($p < 0.05$; ES > 0.8; Large) in all time epochs; and handball -except in the 300 s time epoch in number of acceleration >2 m·s^{-2} where it presents no differences with regard to soccer- is the sport with the smallest number of accelerations and accelerations >2 m·s^{-2} in all time epochs.

Discussion

The purpose of this study was to investigate the differences between the MDS of five different team sports of the same club competing at a professional level. The main finding of this research was that the MDS of official matches are significantly different across team sports, with soccer and rink hockey achieving the greatest values in total distance covered, distance >18 km·h^{-1} and number of actions >18 km·h^{-1}. On the other hand, basketball presented the greatest results in number of accelerations and decelerations >2 m·s^{-2} in 30- and 60-s time epochs. Therefore, athletic staff and team sports coaches should consider the specificity of the MDS across different time epochs in their sports discipline during competition to optimise individual and collective physical match performance.

Due to the larger playing area, continuous clock and the absence of time-outs, soccer achieved the greatest peak values in total distance covered during the 30-s time epoch with major differences compared to all the sports ($p < 0.05$; ES = 1.29 – 1.57), except for rink hockey ($p > 0.05$; ES = 0.21). Nevertheless, the results of this research are lower during the 60-, 180- and 300-s time epochs compared to previous research in soccer competition with professional players from a reserve squad of the same club.[11,22] This could be explained for by the methodology used (GPS versus LPS), the influence of the coaches on the club's playing style and the number of players who are fully conversant with the approach based on ball possession. In addition to soccer, the highest values in total distance covered along the four other larger time epochs (60, 120, 180 and 300 s) were found in rink hockey. The two possible reasons that might explain these results are the fact that the court is fenced off and the use of roller skates. While the former prevents interruptions (e.g., out-of-bounds), stimulating match-play continuity, the latter tend to favour the accumulation of meters covered. For instance, rink hockey players usually prefer to continue rollerblading behind the goals instead of decelerating to execute a sharp change of direction to advance to the opposite goal.

As in total distance covered, soccer and rink hockey also lead MDS values in distance and number of actions >18 km·h^{-1} across all the time epochs measured. In soccer, the fact that the outdoor playing field is significantly larger than indoor courts (Table 2) is conducive to players reaching maximum speeds and subsequently to an increased distance and

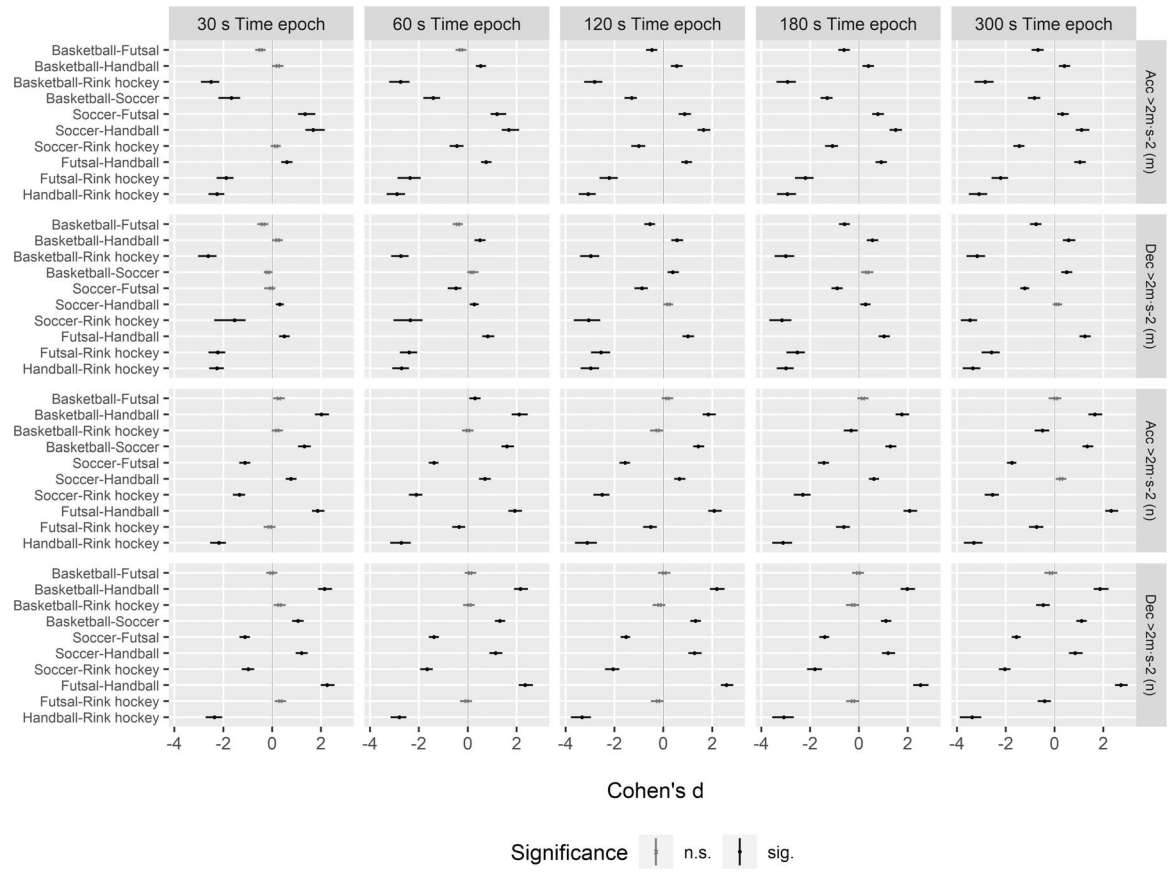

Fig. 2 Post-hoc, effect size analysis (Cohen's d) and it's 95% CI between the professional team sports for the acceleration related variables. Note: The black lines indicate significant differences ($p < 0.05$) between team sports, whereas the grey lines indicate non-significant differences ($p > 0.05$). Acc is acceleration; and Dec is deceleration.

number of actions >18 km·h^{-1}. Rink hockey, on the other hand, has the limitation of the reduced playing court in achieving peak velocities, even although roller skates can help to reach higher speeds than futsal, handball, and basketball. The results of this study are in line with Fernández et al. (2020), who found a MDS of rink hockey match-play in mean relative distance (m·min^{-1}) at high-speed skating (>18 km·h^{-1}) of 78.42 ± 19.89, 54.57 ± 15.18 and 33.14 ± 7.91 in the 60-, 120- and 300-s time epochs, respectively. Similarly, handball achieved greater values in distance and actions >18 km·h^{-1} than futsal and basketball. The latter is played on the smallest court of all the sports examined, with significantly limits actions and distance covered >18 km·h^{-1} in maximal linear efforts. Futsal also covered greater distances at acceleration and decelerations >2 m·s^{-2} compared to handball ($p < 0.05$; ES = 0.49 − 1.23) and basketball in the 120-, 180- and 300-s time epochs ($p < 0.05$; ES = 0.47 − 0.76), even though futsal did not achieve the greatest number of accelerations and decelerations >2 m·s^{-2}. The fact that futsal covered major distances without standing out in terms of number of actions >18 km·h^{-1} and acceleration and decelerations >2 m·s^{-2} could be explained by the fact that futsal players usually cover more meters in a straight line over a smaller number of fast transitions.

Regarding accelerations and decelerations, the available research in soccer [2] and basketball [23] has shown an increased number of high-intensity (2.5 - 3.5 m·s^{-2}) decelerations compared to accelerations following the analysis of average values during matches and training, respectively. Conversely, this study found that distance and number of accelerations >2 m·s^{-2} were higher than decelerations >2 m·s^{-2} in all the sports across all the time epochs examined, which could be because average values, rather than the MDS, were examined, and to the use of different absolute thresholds to categorize high-intensity actions. Besides the comparison of accelerations and decelerations, handball presented the lowest peak values for all the time epochs examined ($p < 0.05$; ES = 0.26 − 3.38). These lower results could be partly explained by two reasons: 1) although handball is considered to be an intensity sport due to the large number of repeat high-intensity jumps, changes of direction, duels and contacts that involve major isometric muscle actions that were not examined in this research, low-intensity activities, such as standing still and walking, have been shown to represent up to 70% of playing time.[24] Moreover, it is worth noting that the fact that there is no specified maximum possession time for attackers and that fouls are not severely punished if they are not excessively aggressive could benefit the slow-paced nature of this sport; and 2) since the team involved in this study had a vertical and aggressive playing style with the clear purpose of increasing the number of possessions with counter-attacks and rapid offensive transitions, all the opposing teams tried to drastically reduce the pace of the match in order to stand a chance against the unbeaten champion of the 2018-2019 Spanish first division (Liga Asobal). Conversely to the minimum acceleration and

deceleration values, basketball achieved the greatest number of accelerations >2 m·s^{-2} during the MDS of 30 s (7.10 ± 1.33), with significant differences between handball and soccer ($p < 0.05$; ES = 1.31 − 2.02) and 60 s (10.34 ± 2.23), with meaningful variation between handball, soccer and rink hockey ($p < 0.05$; ES = 0.29 − 2.10); in similar fashion, basketball also achieved the greatest number of decelerations >2 m·s^{-2} during the MDS of 30 s (6.72 ± 1.33) with significant differences between handball and soccer ($p < 0.05$; ES = 1.05 − 2.15), and the second-highest number of decelerations >2 m·s^{-2} during the MDS of 60 s (9.63 ± 2.30) with meaningful variation between handball and soccer ($p > 0.05$; ES = 1.31 − 2.16). These results are significantly greater than the values found in the research conducted by Vázquez-Guerrero et al. (2020), who concluded a total of 4.9 accelerations >2 m·s^{-2} and 4.6 decelerations >2 m·s^{-2}; and 6.9 accelerations >2 m·s^{-2} and 6.4 decelerations >2 m·s^{-2} during the 30-s and 60-s time epochs, respectively. Since the aforementioned study examined Under-18 players competing in a four-day tournament with three or four consecutive matches, one possible explanation for the increased results discovered in this research with professional basketball players participating in one official league match in the course of the weekend could be the methodological differences in the subjects' age and competition type, in addition to the different tactical models and playing styles.

In conclusion, this study showed multiple significant differences between the MDS of official matches in five different team sports across five different time epochs (30, 60, 120, 180 and 300 s). Sport-specific professionals can use this information to establish the upper limit threshold in the training monitoring process and to optimise drill prescription after manipulating duration and intensity according to the specific objective. Nevertheless, this research was unable to recognize when the MDS appeared during competition or whether the MDS of different variables appear at the same time. Additionally, another potential limitation could be the lack of context during the MDS of match-play, which only include physical parameters without taking the technical and tactical actions involved into consideration. Finally, this study only quantified the MDS of external workload variables during match-play. Therefore, future research should address the inclusion of internal workload variables, such as heart rate, to glean a better understanding of the impact of peak physical demands on players' physiological adaptations.

Conflicts of interest

The Authors declare that they don't have any conflict of interests.

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