Title:

High-intensity demands of 6-a-side small-sided games and 11-a-side matches in youth soccer players

Running title:

Small-sided games and matches in youth soccer

Corresponding author:

Heita Goto

Faculty of Sports Science, Kyushu Kyoritsu University, , Japan

81-(0)93-693-3425

heitagoto@hotmail.com

Co-authors:

JA King

School of Sport, Exercise and Health Sciences, Loughborough University, UK

J.A.King@lboro.ac.uk

ABSTRACT

Purpose. The purposes of the present study were to examine: high-intensity running distance during 6-a-side small-sided games (SSGs) and 11-a-side matches (11M) in youth soccer players using speed and metabolic power approaches and; the magnitude of difference between high-intensity running distance calculated with the two approaches. **Method.** Eleven outfield players (age = 16.3 ± 0.6 years) performed SSGs with three pitch sizes (small SSG (SSGS), medium SSG (SSGM) and large SSG (SSGL)) and 11M. A Global Positioning System (15 Hz) was employed to calculate total distance covered, distance covered at a speed $\geq 4.3\ m \cdot s^{-1}$ (TS) and metabolic power of $\geq 20\ W \cdot kg^{-1}$ (TP). **Results.** The total distance covered increased from SSGS through to SSGL ($P < 0.001$) and was greater during 11M and SSGL compared to other SSGs ($P < 0.01$). TS and TP increased from SSGS (TS vs. TP = 98 ± 55 vs. 547 ± 181 m) through to SSGL (538 ± 167 vs. 1050 ± 234 m, $P < 0.001$). TS and TP during 11M (370 ± 122 vs. 869 ± 233 m) was greater than SSGS ($P < 0.001$ for both) and less than SSGL ($P < 0.05$ for both). The magnitude of difference between TS and TP (%) reduced with an increase in pitch size during SSGs and was greater in SSGS (615 ± 404%, $P < 0.001$) and SSGM (195 ± 76%, $P < 0.05$) and smaller in SSGL (102 ± 33%, $P < 0.01$) compared to 11M (145 ± 53%). **Conclusion.** SSGs can replicate the high-intensity demands of 11M and the speed approach underestimates high-intensity demands of SSGs and 11M compared to the metabolic power approach.

INTRODUCTION

Small-sided games (SSGs) have been commonly used as a training drill by coaches to develop physical fitness (21,25,35) or technical and tactical abilities (27,32,36) of soccer players. Many studies have investigated the variables which influence the physical demands during SSGs (23) and such variables include pitch size (area per player) (7,34), player number (1,3,22,), coach feedback (2,34), training regimen (continuous or interval) (9,24), rule modifications (20), use of goals and/or goalkeepers (10) and prior knowledge of exercise duration (12). Hence, many elements must be considered to control the physical demands during SSGs.

The identification of training modalities which most closely replicate the physical demands of soccer match play is of great interest to coaches and exercise scientists who are concerned with optimizing training stimuli (8,34). To date, only three studies have compared the demands of SSGs and 11-a-side matches (11M) (8,13,28). Unfortunately, within each of these previous studies more than one game-related variable has been manipulated (e.g. player number and pitch size) making it impossible to isolate the independent effect of either. Furthermore, each of these previous studies examined adult participants, and it is recognized that players in the developing stages should not be considered as miniature adults (37). It is therefore necessary to examine the differences in the physical demands between SSGs and 11M in young soccer players whilst modifying only one variable to investigate the specific format of SSGs which mimic the physical demands of 11M.

In recent years, the metabolic power approach has been employed to examine the physical demands of training sessions (15), SSGs (14,39) and match play (33) in elite professional soccer players; with a common use of Global Positioning Systems (GPS) for data collection

(14,15). Metabolic power is obtained by multiplying the estimated energy cost of accelerated/decelerated running on a horizontal level with an assumption that accelerated/decelerated running on a horizontal level is energetically equivalent to uphill/downhill running at a constant speed on an ‘equivalent’ slope. As energy costs are independent of the velocity and the energetics of uphill/downhill running can be described, an estimation of the energy costs of accelerated/decelerated running on a horizontal level can be achieved (33). The metabolic power approach involves accelerations and decelerations whereas the traditional speed approach only includes distances covered at constant speeds. The latter neglects the importance of accelerations and decelerations when estimating metabolic demands (33). Accelerations are a pre-cursor to running at high speeds and during accelerations, a greater neural activation to the working muscles and a higher rate of force production are required compared to a constant speed running (29,33). Even when moving at low speeds, a great amount of metabolic load is imposed on soccer players when acceleration is raised, and decelerations occur as frequently as accelerations in soccer that each significantly contribute to the physical demands of soccer (33). Moreover, the metabolic power approach is more strongly related to energy expenditure compared to the traditional speed approach (5,19).

The high-intensity demands during SSGs (14) and match-play (33) have previously been examined with speed and metabolic power approaches in professional soccer players. The previous study employed 5-a-side, 7-a-side and 10-a-side SSGs with area per player of 75, 98 and 135 m^2, respectively (14). The results showed increases in high-intensity running distance with increases in player number and area per player in both approaches. Moreover, the high-intensity running distance of SSGs were underestimated by the speed approach compared to the metabolic power approach by around 45-350% and the underestimation was greater when the area per player was reduced (14). In addition, the speed approach underestimated the high-intensity running distance during a match by ~45% in professional soccer players compared to the metabolic power approach (33). Although the high-intensity demands of SSGs and 11M have been investigated in the separate studies using two approaches (speed vs metabolic power), from the authors' knowledge, such variables have not been examined in a single study with the same participants (14,33,39). Furthermore, metabolic power related data on SSGs and 11M is only available on senior and elite youth players (14,33,39). Since physiological and physical responses during SSGs and 11M differs depending on standard of play (30,39), an investigation of the high-intensity demands of SSGs and 11M using two approaches (speed vs metabolic power) in non-elite youth players would provide a greater understanding of relationships between the two approaches (speed vs metabolic power) during SSGs and 11M in this particular category of players. Such investigation would support coaches and sports scientists to provide group specific training programs and maximize performance enhancement.

Therefore, the aims of the present study were to examine: 1) the high-intensity demands of SSGs and 11M in youth soccer players using two approaches (speed vs metabolic power) and: 2) the magnitude of difference between running distance calculated with speed and metabolic power approaches during SSGs and 11M.

METHOD

Participants

The subjects were 11 outfield players from the same soccer team who competed in regional level competitions (age = 16.3 ± 0.6 years; height = 170.1 ± 6.4 cm; body mass = 59.8 ± 7.5 kg; playing experience = 6.1 ± 1.3 years; 10 m sprint time = 1.74 ± 0.08 s; Yo-Yo intermittent recovery test level 1 = 1316 ± 289 m). The team trained five times and played one match per week on average during a season and all training involved technical based sessions. Subjects were provided with a written and verbal explanation of the study including experimental protocols and all measurements to be taken. Each player signed an informed assent form and completed a health screen questionnaire prior to participation in the study. Each player's parent signed a consent form prior to the start of the study. Players were free to withdraw from the study without giving any reasons. The study was approved by a University Ethical Committee.

6-a-side small-sided games and 11-a-side matches

The participants performed 6-a-side SSGs (five field players and a goalkeeper) with three different pitch sizes (small SSG (SSGS), medium SSG (SSGM), large SSG (SSGL)) and 11M as part of training sessions. Established characteristics of SSGs and 11M are shown in table 1 and all SSGs and 11M employed the same pitch length to width ratio. In SSGs, each team contained two central defenders, a defensive midfielder, a central attacking midfielder and a striker. A playing system of 4-2-3-1 was only allowed during 11M. Participants played their natural playing positions during SSGs and 11M. The players included in each team were generally fixed for all SSGs and 11M but there was a maximum of one player difference in a team in some sessions due to injuries or unavailability. The players in each team were selected by the coach who was asked to include players with similar ability to balance the strength of the teams.

All data collection took place on the same pitch which was a third generation synthetic astroturf (Grand Grass F-M DS, Mizuno corporation, Osaka, Japan). Laws of the game (40) were applied during SSGs and 11M but the offside rule was neglected during SSGs. Each of the SSGs and 11M were conducted four times during six weeks and two to three sessions took place in each week. They were conducted in a counterbalanced order and the day after a match was avoided. All participants took part in each of the SSGs and 11M for 2.7 ± 0.8 times (range = 2-4 times). Each session started with the same warm-up from 15:00 (approximately 30 minutes) which involved static and dynamic stretches, running at various speeds from jogging to sprinting and technical drills. The duration of all SSGs and 11M was 35 minutes because that was the duration of a half of participants' official matches. A multi-ball system was employed to minimise non-playing time and similar verbal encouragement was given by the coach during SSGs and 11M as coaches' feedback can influence physical demands (2,34). The environmental temperature was between 24 and 28 ºC and humidity between 63 and 85% during the data collections (rainy days were avoided).

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Physical demands

The previously reported equation has been employed to estimate metabolic power and assumed energy cost of running at constant speed was 3.6 $J \cdot kg^{-1} \cdot m^{-1}$ (33).

$$\text{Metabolic power} = EC \cdot v$$

Where, EC = the energy cost of accelerated running on grass ($J \cdot kg^{-1} \cdot m^{-1}$) = $(155.4 \cdot ES^5 - 30.4 \cdot ES^4 - 43.3 \cdot ES^3 + 46.3 \cdot ES^2 + 19.5 \cdot ES + 3.6) \cdot EM \cdot KT$, ES = the equivalent slope = $\tan(90 - \arctan g/a_f)$, g = Earth's acceleration of gravity; a_f = forward acceleration; EM = the equivalent body mass = $[(a_f^2 \cdot g^{-2}) + 1]^{0.5}$, KT = a constant = 1.29, v = running speed ($m \cdot s^{-1}$).

In addition to total distance covered, high-intensity physical demands were analysed with the assessment of speed and metabolic power. The distance covered at a speed $\geq 4.3\ m \cdot s^{-1}$ (TS) (33) and metabolic power of $\geq 20\ W \cdot kg^{-1}$ (TP) (14,15) were calculated. These values were chosen because $20\ W \cdot kg^{-1}$ is the metabolic power when running at a constant speed of approximately $4.3\ m \cdot s^{-1}$ on natural (33) and artificial (38) grass. Physical demands were analysed with 15 Hz (5 Hz signal interpolated to 15 Hz) GPS technology (SPI HPU, GPSports, Canberra, Australia) which was positioned on the upper back in a custom-made vest. This particular device has been reported to possess less than 1% error in estimating the total distance covered when 8 laps of a team sport simulation circuit (165 m) was completed. The circuit included resting, different type of movements (straight walking/running, figure eight agility run, 90 degrees turning), various speeds (walking to sprinting) and fast accelerations/decelerations (26). Moreover, there was a <5% difference in maximal speed during 30 m sprint with split times at 10 and 20 m between the values estimated using GPS and photoelectric timing gates (26). Moreover, inter-unit reliability (percentage typical error of measurement) for total distance covered, distance covered at $< 3.9\ m \cdot s^{-1}$, $3.9\text{-}5.6\ m \cdot s^{-1}$ and $>5.6\ m \cdot s^{-1}$ were 1.9, 2.0, 7.6 and 12.1%, respectively (26). At least 8 satellites (mean ± SD = 9.5 ± 0.8 satellites) were connected during data collection which is the minimum number of satellites required to allow an accurate measurement (41,42) and mean horizontal dilution of position was 1.2 ± 0.2 during data collections. Total distance covered, TS and TP were calculated using Team AMS software version R1.2016.4 (GPSports, Canberra, Australia) and the software filtered through all data concerning velocity, acceleration and deceleration to eliminate noise before calculating the distance.

Statistical analyses

The mean values from SSGs and 11M for each player were calculated before calculating group means and conducting the statistical analyses. The magnitude of difference was calculated by dividing an absolute difference between TS and TP by TS and multiplied by 100. Data were normally distributed as examined by a Kolmogorov-Smirnov test. Levene's Test revealed that variances were unequal for SSGs and 11M. Hence, one-way analysis of variance with Games-Howell post hoc test was employed to compare physical demands between 11M and SSGs. The effect size (η^2) was calculated and values of 0.01, 0.06 and above 0.15 were considered as small, medium and large, respectively (11). Levene's Test revealed that variances were equal for TS and TP in each of the SSGs and 11M therefore an independent sample t-test was employed to assess whether or not there were statistically significant differences between TS and TP. The effect sizes (*d*) for these differences were calculated as (mean A – mean B)/ (pooled SD) and values of 0.2, 0.5 and above 0.8 were considered to represent small, moderate and large differences, respectively (11). The level of statistical significance was set at $p < 0.05$. Results are presented as mean ± standard deviation (SD) and IBM SPSS 22.0 was used for all the statistical analyses.

RESULTS

Comparison of physical demands between SSGs

Total distance covered, TS and TP increased from SSGS through to SSGL ($P < 0.001$ for all, $\eta^2 = 0.44$-0.65) (figure 1-3).

------------------------- Figure 1 to 3 here -------------------------

Comparison of physical demands between SSGs and 11M

The total distance covered during 11M was similar to SSGL and greater than SSGS and SSGM ($P < 0.001$ for all, $\eta^2 = 0.58$) (figure 1). TS during 11M was approximately four times greater than SSGS ($P < 0.001$) and ~45% less than SSGL ($P < 0.001$) ($\eta^2 = 0.65$) (figure 2). TP during 11M was ~59% greater than SSGS ($P < 0.001$) and ~21% less than SSGL ($P < 0.05$) ($\eta^2 = 0.44$) (figure 3).

Difference between TS and TP

TP was greater than TS in all SSGs and 11M (~450 to ~520 m, $P < 0.001$, $d = 1.3$-1.9 for all) (figure 2 and 3). The magnitude of difference between TS and TP (%) reduced with an increase in pitch size from ~620% for SSGS to ~100% for SSGL ($P < 0.001$, $\eta^2 = 0.51$) (figure 4). Moreover, the magnitude of difference between TS and TP (%) in 11M was greater than SSGL ($P < 0.01$) and less than SSGS ($P < 0.001$) and SSGM ($P < 0.05$) ($\eta^2 = 0.51$) (figure 4).

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DISCUSSION

This is the first study that examined the high-intensity demands of 6-a-side SSGs (three different pitch sizes) and 11M using speed and metabolic power approaches in youth soccer players. The main findings of the present study were that: 1) the high-intensity demands of 6-a-side SSGs increased when the pitch size was enlarged regardless of approaches (speed vs metabolic power); 2) TS and TP during 11M and SSGM were similar; 3) the speed approach underestimated the high-intensity demands of 6-a-side SSGs and 11M compared to the metabolic power approach; 4) the underestimation of high-intensity demands during SSGs increased with a reduction in pitch size; and 5) the underestimation of high-intensity demands during 11M was less than SSGM.

The first major finding of the current study was that total distance covered, TS and TP during 6-a-side SSGs, increased when pitch size was expanded. For total distance covered, a previous study of 15-year-old boys during 6-a-side SSGs agreed with the current findings (7). However, the previous study reported that TS was only greater in medium and large compared to small pitch size with no differences between medium and large pitches (7). This disagreement is possibly because the previous study employed a smaller pitch size ratio between medium and large SSGs compared to the current study (medium: large = current, 1: 2 vs previous, 1: 1.5) (7). Moreover, similar findings to the current study in TP have been demonstrated in professional soccer players when player number and area per player were increased together (14).

The total distance covered during SSGL and 11M in the current study was similar to the previous studies. The current participants covered ~4000 m during 11M and when the distance was adjusted to match playing time, the distance was consistent with under-16 soccer players from England (16,18) and Qatar (6). Moreover, the distance covered during 11M was similar to SSGL which suggests that total distance does not differ when player number changes as long as the area per player is the same. However, the previous studies reported that a change in player number influences (22) or does not influence (1) total distance and total distance is a poor indicator of global work rate in SSGs (22) and 11M (30).

The second major finding of the current study was that TS and TP during 11M were greater than SSGS, less than SSGL and similar to SSGM. A previous study which examined the physical demands of 6-a-side SSGs and 11M in semi-professional soccer players concluded that SSGs are played at a higher intensity than 11M when area per player of SSGs was two-thirds of 11M (SSG vs 11M = 200 vs 300 m^2) (8). Conversely, the area per player of SSGM was roughly half of 11M in the current study (SSGM vs 11M = 165 vs 325 m^2). These findings suggest that 6-a-side SSGs with roughly half the area per player of 11M provides a similar high-intensity demand to 11M; whereas 6-a-side SSGs with around two-thirds and greater area per player of 11M offer a greater high-intensity demand than 11M. In addition, players perform less high-intensity running during 6-a-side SSGs than 11M when area per player of SSGs is approximately a quarter of 11M.

The third major finding of the current study was that TP was greater than TS during all SSGs and 11M. Similar findings have been reported during various SSGs (14,39), 11M (33) and training sessions (15). In the current study, the magnitude of difference between TS and TP during SSGs were ~100 to ~620% and that was reduced with pitch size from SSGS through SSGL. Similar values (~20% to ~349%) (14,39) and a trend (14) have been observed in the previous studies on SSGs. However, the previous study modified player number and area per player together (14) and the current study is the first to demonstrate that a modification of area per player alone still alters the same relationship between area per player and magnitude of difference between TS and TP in SSGs. The variations in the underestimation of high-intensity demands in SSGs exists because players are required to produce a greater or lesser proportion of high-intensity activities at constant high speeds depending on pitch size of SSGs and that results in decreases or increases in the production of explosive accelerations and decelerations (14,15). Although the metabolic power approach reflects metabolic internal loads, and running distance calculated by the speed approach demonstrates external loads, the employment of the metabolic power approach probably offers a more valid indication of the high-intensity demands of SSGs and 11M in youth soccer player as metabolic power approach includes demands of accelerations/decelerations (14).

A further major outcome of the current study was that the magnitude of difference between TS and TP during 11M was ~145%. This value seems to be greater than the magnitude of difference reported from match play of professional soccer players (~45%) (33). The professional players covered a greater proportion of total match distance by high-intensity running (current vs professional: 4.3 $m \cdot s^{-1}$ vs 4.4 $m \cdot s^{-1}$) compared to the participants in the current study (current vs professional: 9% vs 18%) (33) which suggests that the professional players produced a larger proportion of high-intensity activities at constant high speeds and a less amount of explosive accelerations and decelerations at low speeds compared to the participants of current study (14,15). Hence, the speed approach underestimates high-intensity demands of match play compared to metabolic power approach especially in the players who covers less distance with high speeds.

Given that TS and TP did not differ between SSGM and 11M in the current study, the magnitude of difference between TS and TP was greater during SSGM compared 11M. The rationale for this finding is unknown but modification of player number alone has been shown to influence demands of SSGs including heart rate (1,3,22) and running distance (1,22) related variables that different number of players employed in SSGM and 11M may explain the current result. The current study mainly focused on the influence of pitch size modification on physical demands during SSGs with a fixed player number and future studies should investigate the influence of player number on high-intensity demands and the underestimation of speed approach compared to metabolic power approach.

There are three possible limitations to the current study. Firstly, the current study compared the high-intensity demands of SSGs and 11M with a playing time of 35 minutes in all sessions. However, a single bout of SSGs is traditionally much shorter than the duration employed in the current study (3-8 minutes) (17) and longer duration would reduce distance covered in high speeds and frequency of high intensity activities (24). Hence, it is important to note that an employment of SSGs with a different duration to the current study may result in players showing different physical responses. Secondly, the current study could not include heart rate (HR) in the analysis due to having invalid HR data in many occasions. HR data may have supported the analysis by providing physiological loads which is different to displacement measures. Finally, the current study did not control tactical aspects of SSGs and 11M. Although tactical differences can influence physical responses during SSGs (31) and 11M (4), this is an under researched area that such aspects may need to be explored further in the future research.

CONCLUSION

The current findings demonstrate that 6-a-side SSGs can replicate the high-intensity demands of 11M in youth soccer players when the area per player of the SSGs is approximately half of 11M. On the other hand, two-thirds or greater area per player of 11M provides a greater high-intensity demand during 6-a-side SSGs and a quarter of the area per player of 11M would require less high-intensity demand during 6-a-side SSGs compared to 11M. Moreover, total distance covered and high-intensity running distance during 6-a-side SSGs increase with enlargement of pitch size regardless of approach (speed vs metabolic power). However, the speed approach underestimates the high-intensity demands of SSGs and 11M compared to the metabolic power approach; and the underestimation increases exponentially with a reduction in pitch size in SSGs. Therefore, coaches and sports scientists should pay attention to methodology for monitoring players (speed vs metabolic power) and are advised to carefully choose pitch size of SSGs together with number of players per team depending on the aim of training sessions.

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FIGURE LEGENDS

Figure 1. Total distance covered during SSGs and 11M. Significantly different at $*p < 0.05$ $**P < 0.01$. $***P < 0.001$. SSGS = small small-sided game; SSGM = medium small-sided game; SSGL = Large small-sided game; 11M = 11-a-side match.

Figure 2. TS during SSGs and 11M. Significantly different at $*p < 0.05$ $**P < 0.01$. $***P < 0.001$. SSGS = small small-sided game; SSGM = medium small-sided game; SSGL = Large small-sided game; 11M = 11-a-side match, TS = distance covered at a speed $\geq 4.3\ m \cdot s^{-1}$.

Figure 3. TP during SSGs and 11M. Significantly different at $*p < 0.05$ $**P < 0.01$. $***P < 0.001$. SSGS = small small-sided game; SSGM = medium small-sided game; SSGL = Large small-sided game; 11M = 11-a-side match, TP = distance covered at metabolic power of $\geq 20\ W \cdot kg^{-1}$.

Figure 4. Magnitude of difference between TS and TP in SSGs and 11M. Significantly different at $*p < 0.05$ $**P < 0.01$. $***P < 0.001$. SSGS = small small-sided game; SSGM = medium small-sided game; SSGL = Large small-sided game; 11M = 11-a-side match, TS = distance covered at a speed $\geq 4.3\ m \cdot s^{-1}$, TP = distance covered at metabolic power of $\geq 20\ W \cdot kg^{-1}$.

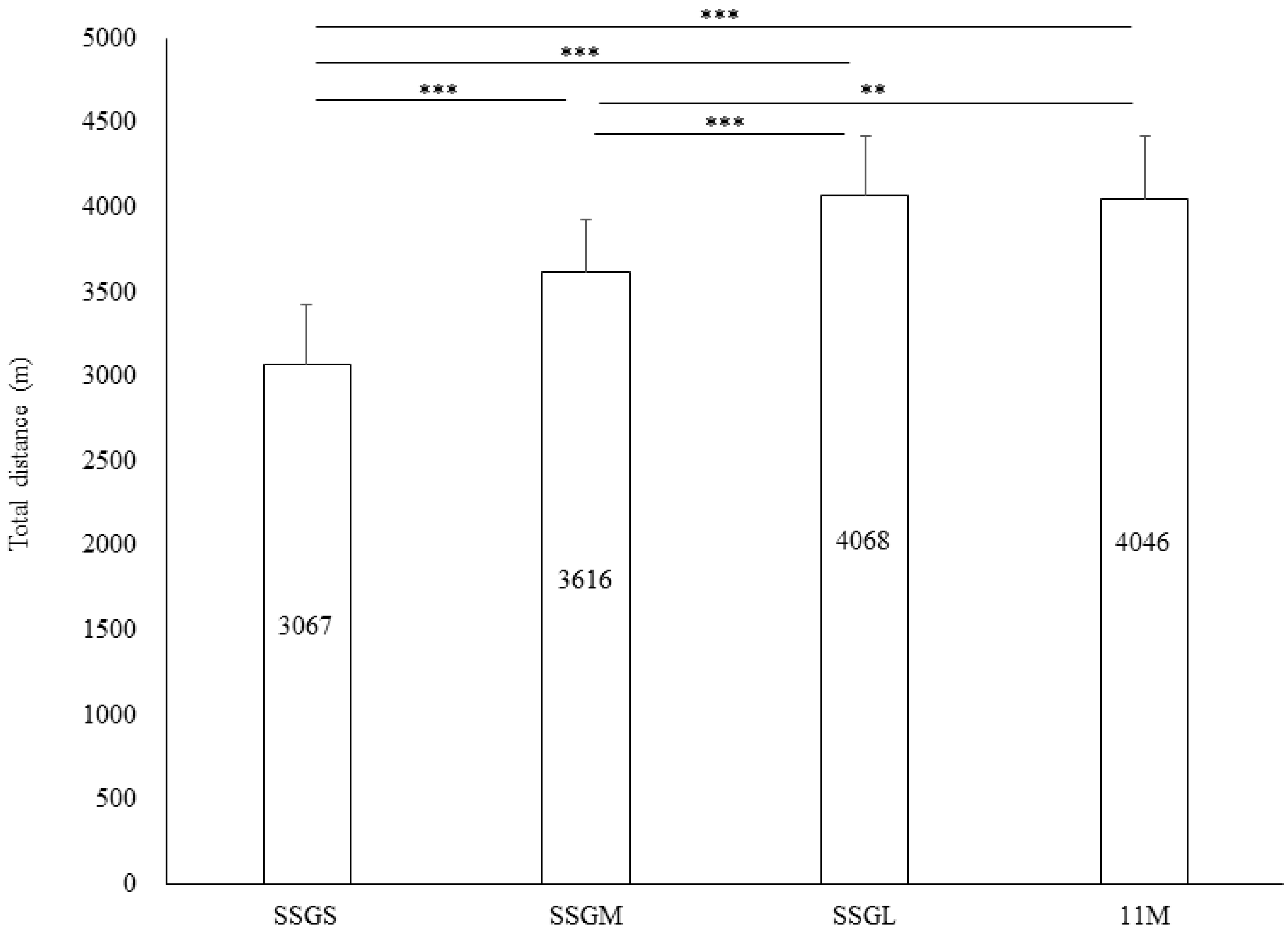
TABLES

Table 1. Established characteristics of SSGs and 11M.

	SSGS	SSGM	SSGL	11M
Pitch length (m)	39	55	78	105
Pitch width (m)	25	36	50	68
Playing area (m^2)	975	1980	3900	7140
Area per player (m^2)	81	165	325	325
Duration (min)	35	35	35	35
Goalkeepers	Yes	Yes	Yes	Yes
Offside rule	No	No	No	Yes

466

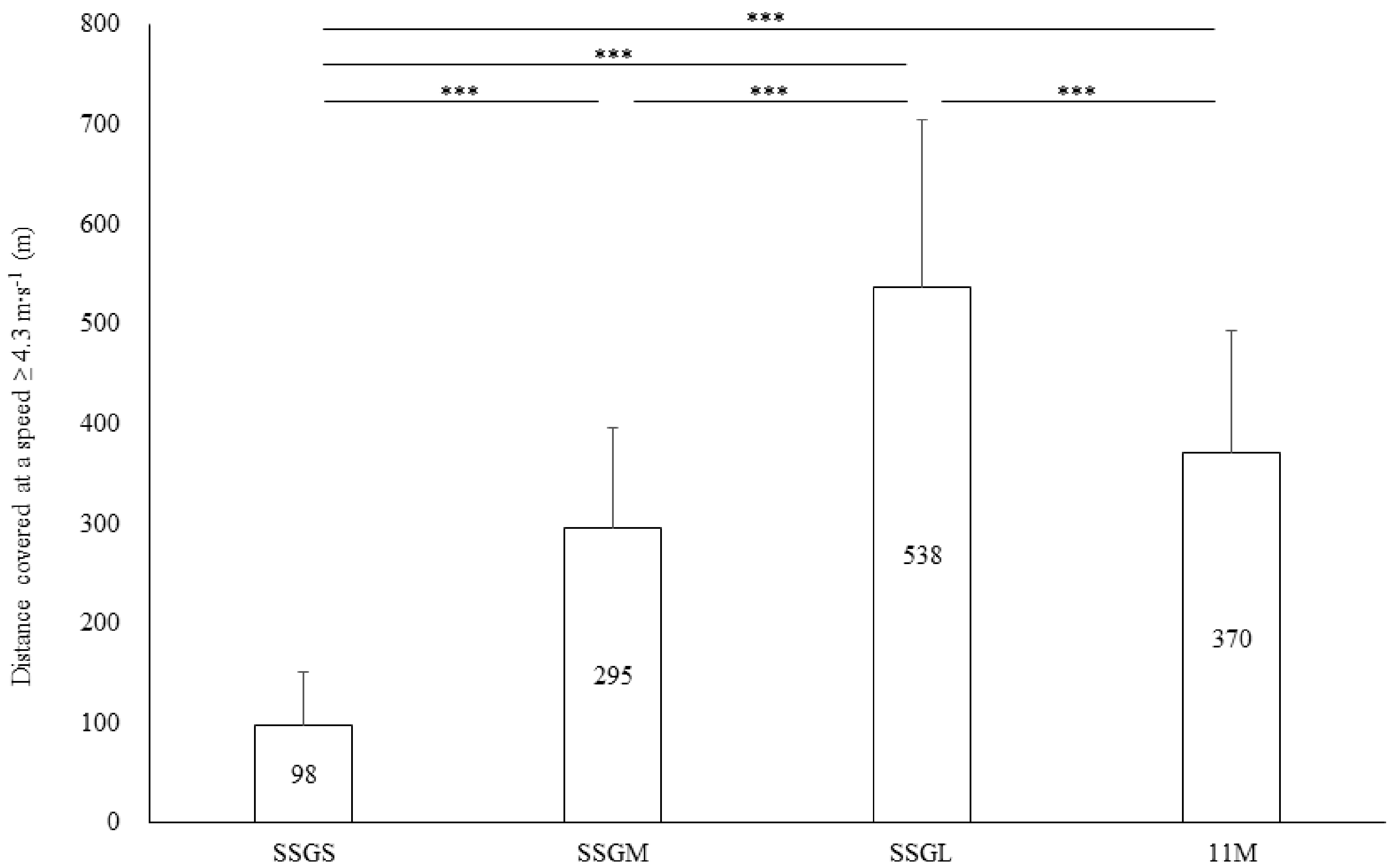
Figure 1


***
***
***
**
***
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Total distance (m)
3067
3616
4068
4046
SSGS
SSGM
SSGL
11M

467

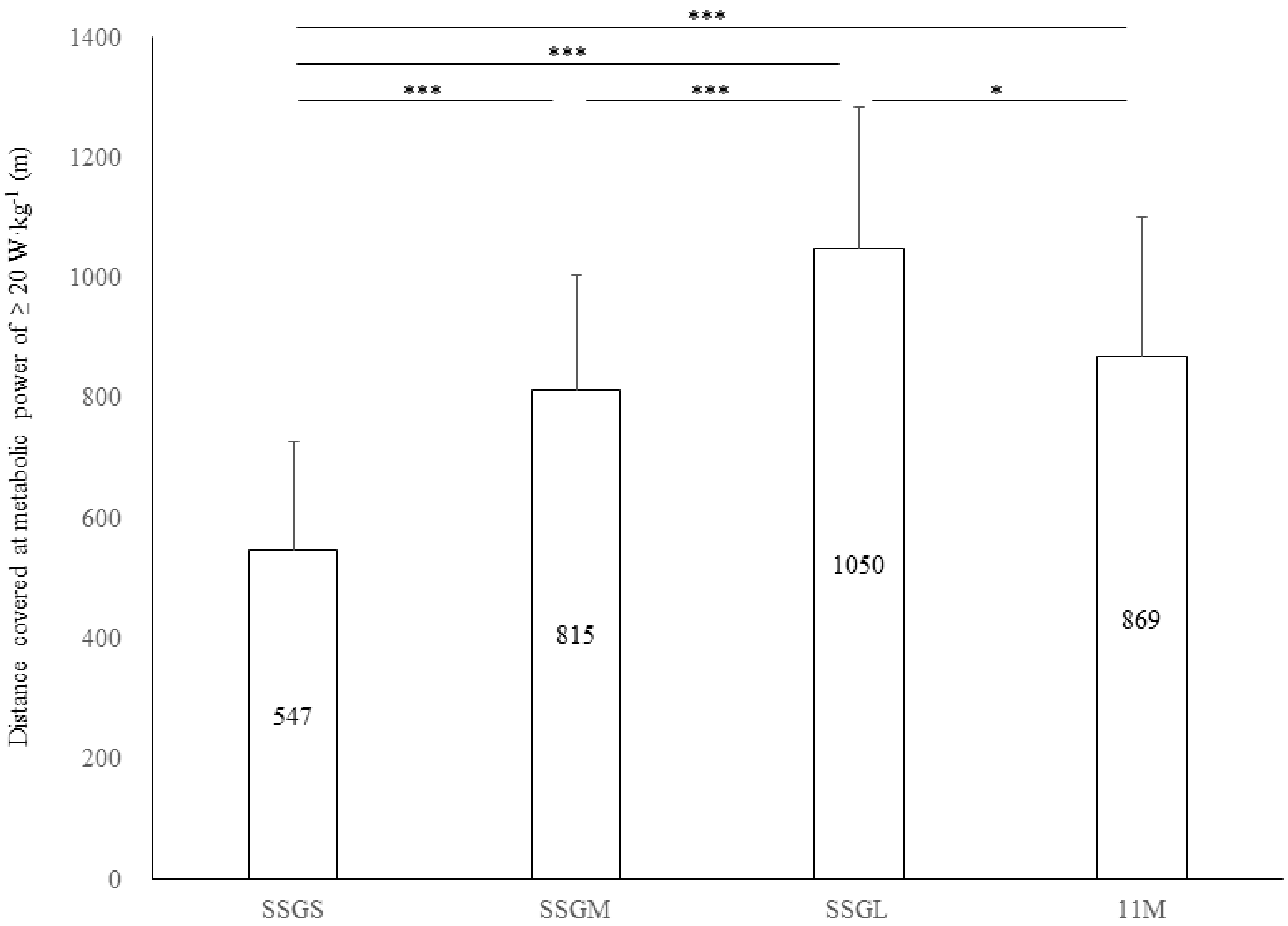
468

Figure 2


Distance covered at a speed ≥ 4.3 m·s-1 (m)
800
700
600
500
400
300
200
100
0
***
***
***
***
***
98
295
538
370
SSGS
SSGM
SSGL
11M

469

Figure 3

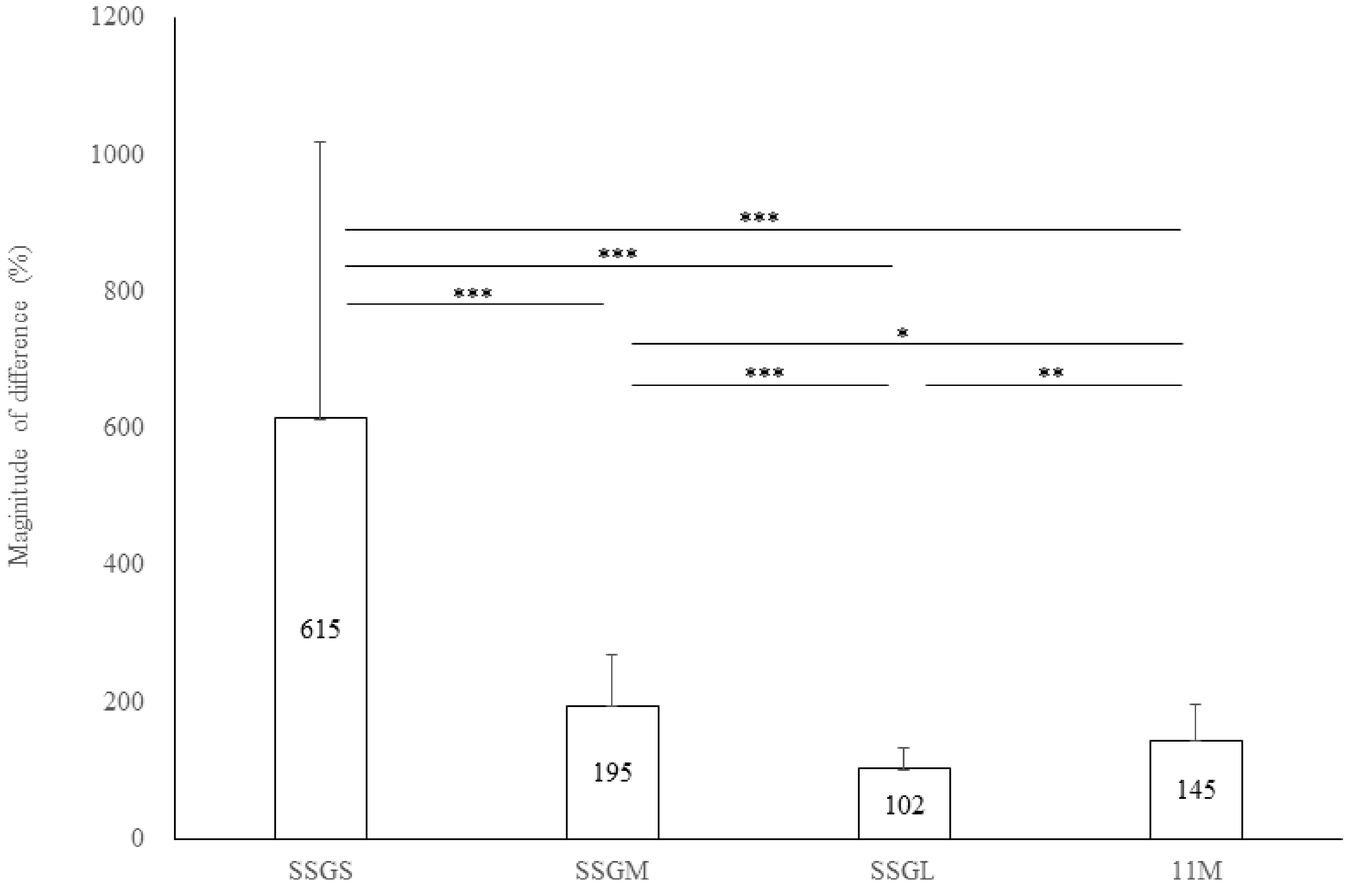


***
***
***
***
*
1400
1200
1000
800
600
400
200
0
Distance covered at metabolic power of ≥ 20 W·kg-1 (m)
547
815
1050
869
SSGS
SSGM
SSGL
11M

470

471

Figure 4


Magnitude of difference (%)
1200
1000
800
600
400
200
0
615
195
102
145
***
***
***
*
***
**
SSGS
SSGM
SSGL
11M