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Original Article

External and internal motor load in Italian young beach soccer players: A pilot study

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Abstract
Purpose. The primary aim of this study was to asses the internal and external match demands of young beach soccer players during an official match. The secondary aim was to evaluate how these demands compared to those of 11-a-side soccer **Materials and methods.** The study involved 24 young soccer players under the age of 17 (all outfield players). Performance assessments were performed on a sand field (35 x 28 m) with beach soccer ball, over three 12-min periods. Internal physiological indicators (heart rate, RPE) and external indicators (total distance, distance/per minute, peak speed, ecc) were collected during and after the match. **Results.** The internal load values obtained show that the beach soccer competition imposes high cardio-vascular intensity on the young soccer player: about 70% of the distance covered results in a HR value between 80% and 100% of HRmax, with an average HR of about 95% of HRmax. The playing time for each player was 17.11±4.23 minutes. The total distance covered and the distance achieved per minute of play were 1733.21±280.76 meters and 83.95±6.29 meters, respectively. The equivalent distance was 1957.98±320.29 meters. The peak speed reached by the young soccer players was 20.01±0.97 km/h while the average speed observed was 5.12±0.52 km/h. The distance measured in moderate- and high-intensity running was significantly lower than the value of low-intensity running ($p<0.05$). The metabolic power intervals showed that the young soccer players ran 1480.46 ± 236.48 meters at low power, 199.45 ± 49.56 meters at high power, 46.13 ± 14.25 at very high power, and 7.43 ± 6.57 meters at maximum power. The values at high power ($p<0.05$), very high power ($p<0.05$) and maximum power ($p<0.001$) were significantly lower than those at low power. **Conclusions.** The performance profile of the young beach soccer player imposes high heart rate values and modest mechanical load during official competition. The performance profile is very different from that of the young 11-a-side soccer player. Beach soccer can be considered a sport that complements the physical condition of the 11-a-side soccer player.
Keywords: sand, beach soccer, young soccer player, external load, internal load

Introduction

The spread of soccer around the world and the increase in membership has also generated relevant attention to the disciplines derived from 11-a-side soccer: futsal and beach soccer (Sannicandro et al., 2024; Esposito et al., 2024). Beach soccer is welcomed into Fédération Internationale de Football Association (FIFA) in 2004, and since 2009, every 2 years, the FIFA Beach Soccer World Cup is held. Becoming a FIFA member gave beach soccer the support to jump onto the world's sporting stage, taking a prominent place in the worldwide sporting landscape.

Today, more than 200 countries around the world embrace the sport, with more than 30 top-level international events held annually, featuring national and club teams, with both men's and women's competitions. Since 2020 in Italy, the Youth and School Sector of the Italian Football Federation (YSS-FIGC) has expanded opportunities for beach soccer practice among young people and has been organized in regional and national competitions for the Under 15 and Under 17 categories. The game is played five-a-side (i.e., four on-court players and one goalkeeper), in a 35-37 × 26-28 m court, with a 5.5 × 2,2 m goal post and an unlimited number of substitutions. The high energy expenditure of the official match requires the coach to perform a large number of changes to allow adequate recovery from fatigue.

A beach soccer match consists of three halves of 12 min separated by a 3 min break, played on a sandy surface. Given that the game-clock is stopped for some events (i.e., ball out of the court, faults, corners). Sand provides a dynamic and challenging environment with specific energy expenditures, which requires athletes to adapt their movement and develop a range of sport-specific skills, such as ball control

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For this reason, recent research has focussed on the differences between conventional and sandy surfaces (Kumaravelu, 2022; Pereira et al., 2021; Rago et al., 2019; Sannicandro et al., 2023; Cetolin et al., 2021; D'Elia et al., 2020; Gaudino et al., 2013). The use of sand in soccer training has found widespread use because it allows numerous training purposes to be achieved.

Indeed, sand surface has been proposed as an alternative training tool to improve body composition, exercise intensity, and lactate production (Rago et al., 2019) or to bring the injured player closer to return to play and reduce the injury risk (Arazi et al., 2016; Binnie et al., 2014). Despite the low specificity of the surface compared to natural grass and artificial turf, training on sand has often been proposed with the goal of promoting high internal loads with drills that are supposed to report lower external loads (Binnie et al., 2014; Cetolin et al., 2021). It has been shown that sand training may induce a considerable amount of elastic energy dissipation, increasing the energy cost and the level of muscle activation (Mirzaei et al., 2013) and might represent an alternative to increase overload during training (Pereira et al., 2021).

Movement difficulties in sand may be due to lower musculo-tendon efficiency (Sanchez-Sanchez et al., 2020; Lejeune et al., 1998) or increased hip and knee flexion (Sanchez-Sanchez et al., 2020; Pinnington & Dawson, 2001) as a result of a larger impact reduction in sand, even more pronounced during the acceleration phase or in short sprints because of longer contact times.

Although this unconventional surface has attracted the attention of research to understand the benefits of performing certain athletic exercises, to date there remains a gap in literature regarding functional demands of an entire soccer match on sand in young soccer players. So far, only one study on adult soccer players has investigated the internal and external load parameters, however, observing competitions with a highly variable duration between 20 and 36 minutes (Castellano & Casamichana, 2010). However, in recent years, the standardization of game regulations has established that the match consists of 3 halves of 12 minutes each so it is necessary to re-analyze the pattern of performance in all levels of sports qualification.

In this regard, it is known that the increased energy expenditure measured on sand also results in up to 2-3 times greater lactate accumulation compared to running on harder surfaces at the same speeds (Sanchez-Sanchez et al., 2020; Zamparo et al.,1992; Leyeune et al.,1998); but the effects of running on sand at higher speeds, i.e., >11 km/h, and for longer periods, i.e., greater than 10 minutes, remain poorly explored (Sanchez-Sanchez et al., 2020). Updating this knowledge is possible through the refinement of available equipment and technology.

The use of wearable technologies, such as global positioning systems (GPS) or heart rate monitors, provides information on the external and internal load imposed on the players and allows quantification of the demands of competition for different levels of competition. Depending on the specifications of the wearable device, both physiological responses (e.g., heart rate) and certain parameters that characterize performance (e.g., total distance, running speed, number of sprints, etc.) can be recorded (Jagim et al., 2020; Bourdon et al., 2017). This information allows staffs to plan training sessions (Hernandez-Martin et al., 2020; Strauss et al., 2019) .

For these reasons, the primary aim of this study were to determine the internal and external match demands of young beach soccer players during an official match. Furthermore, a secondary aim was to understand the extent to which the demands of the beach soccer competition deviate from those of 11-a-side soccer.

Materials and methods

Study participants

24 young soccer players (all movement players) participated to the study (average age: 16.5 ± 0.4 years, weight: 68.2 ± 4.4 kg; height: 178.1 ± 3.5 cm, age training: 8,2 ± 2,1). The study included all the players who at the time of the survey did not report injuries, had been training and participating in training sessions for at least 3 weeks. All soccer players were used to work with GPS monitoring systems and heart rate monitors.

For data to be included in our analysis, players had to participate for a minimum of five minutes of live time, not suffering injury during the match (Garcia et al., 2022). Each player was informed about the research design and the requirements, benefits, and risks of the study, and parents gave informed consent before the start. The study was conducted in accordance with the principles contained in the Declaration of Helsinki.

Study organization

For the analysis of the internal load, heart rate (HR) and perception of effort (RPE) parameters were measured. HR detection was conducted with a telemetry system and heart rate monitors (Polar Electro Oy, Kempele, Finland). The analysed values are the average HR and the HR peak, both in beats per minute (bpm) and in percentage referred to the maximum HR.

For the detection of the RPE - Ratings of Perceived Exertion, the Borg scale CR10 was used (Borg, 1982). During the match, the players were monitored using global positioning system (GPS) instrumentation at 18.18 Hz (GPEXE® SYSTEM, EXELIO srl, Udine, Italy) recently validated (Hoppe et al., 2018). The parameters detected and examined are the total distance covered (m), the distance covered per minute (m), the peak speed (km/h), the average metabolic power (W/kg), the average metabolic power (W/kg) expressed during the active phases (MPE avg power) and during the recovery phases (MPE rec avg power), the number of accelerations (> 2 m/s) and decelerations (< -2 m/s) and the equivalent distance (m). The covered distance was also monitored at different speeds: walking (< 7.30 km/h), running at low intensity (7.30 - 14.50 km / h), running at moderate intensity (14.50 - 19.90 km/h), running at high intensity (19.90 - 25.20 km/h) and in sprints with speed > 25.2 km/h (Rampinini et al., 2007) and the covered distance with different power intensities: low power (< 20.00 W/kg), high power (20.00 - 35.00 W/kg), very high power (35.00 - 50.00 W/kg) and maximum power that is > 50 W/kg (Osgnach et al., 2010).

Performance was carried out on a sand field (35 x 28 m) with beach soccer ball, for 3 times of 12 min each. At the end of the competition, the RPE value was measured according to the usage protocol (Borg, 1982).

Statistical analysis

Due to the nature of the study and the small sample the data are mainly presented in descriptive terms, using means and standard deviations (±SD).

The Kolmogorov–Smirnov test established the normal distribution of the sample. An independent samples *t*-test was used to compare the results regarding the FC range and run intensities. The level of significance was set to $p < 0.05$. All the statistical analyses were performed using SPSS 22.0 for Windows (SPSS Inc, Chi cago, USA).

Results

a) Internal load values

Mean HR recorded during the matches was 190.11±10.61 beats per minute (bpm), which corresponded to 94.41±2.64% of HRmax being 202 bpm. Players spent the greatest amount of distance in the > 90% of HRmax zone (Fig.1) and spent a combined total of 69% of the total distance in the HIHR zones of 80-90% and 90–100% of HRmax (Table 1). The distance traveled in the 71-80%, 81-90% and >91% ranges were significantly different from the 61-70% range (p<0.05).

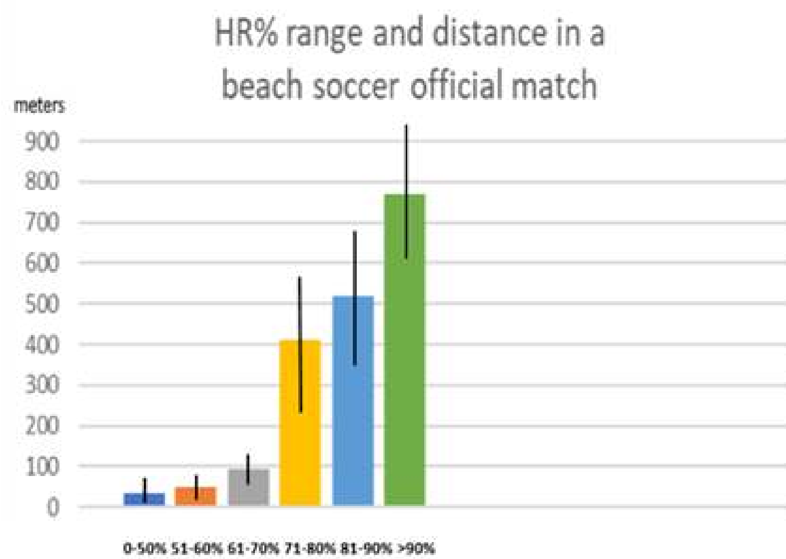

Figure 1. Range of HR% and distance in a beach soccer official match.

% HR range	Distance (m)	p value
0-50%	33.11±37.55	
51-60%	49.22±20.02	
61-70%	92.18 ± 30.83	
71-80%	409.65 ± 463.81	0.03*
81-90%	518.15 ± 220.22	0.02*
> 90%	769.43 ± 670.28	0.02*

Table 1. Heart Rate range and distance traveled in a beach soccer official match. * Significantly different from range 61-70%.

The RPE value expressed at the end of the competition was equal to 7.38±1.33.

a) External load values

The playing time for each player was 17.11±4.23 minutes. The total distance covered and the distance achieved per minute of play were 1733.21±280.76 meters and 83.95±6.29 meters, respectively. The equivalent distance was 1957.98±320.29 meters. Peak speed reached by the young soccer players was 20.01±0.97 km/h while the average speed observed was 5.12±0.52 km/h.

The average metabolic power was 5.89±0.53 W/kg; the average metabolic power expressed during the active phases (MPE avg power) and during the recovery phases (MPE rec avg power) were 18.89±0.66 W/kg and 4.43±0.58 W/kg, respectively. The number of accelerations and decelerations were 17.96±4.48 and 11.36±2.65, respectively. Young soccer players walked for 891.62±135.21 meters, 727.31±148.25 in low intensity running, 111.27±43.39 meters in moderate intensity running, 3.25±3.82 meters in high intensity running.

The distance measured in moderate- and high-intensity running was significantly lower than the value of low-intensity running ($p<0.05$). The metabolic power intervals showed that the young soccer players ran 1480.46 ± 236.48 meters at low power, 199.45 ± 49.56 meters at high power, 46.13 ± 14.25 at very high power, and 7.43 ± 6.57 meters at maximum power. The values at high power ($p<0.05$), very high power ($p<0.05$) and maximum power ($p<0.001$) were significantly lower than those at low power (Table 2).

Table 2. External motor load variables. * Significantly different from low intensity running distance; # Significantly different from low-power distance

Variable	Beach soccer player value	p value
Play time for each player (min)	17.11±4.23	
Total distance (m)	1733.21±280.76	
Distance/min (m)	83.95 ± 6.29	
Maximum speed (km/h)	20.01 ± 0.97	
Avg speed (km/h)	5.12 ± 0.52	
Avg Metabolic power (W/kg)	5.89 ± 0.53	
MPE avg power (W/kg)	18.89 ± 0.66	
MPE rec avg power (W/kg)	4.43 ± 0.58	
Acceleration (n°)	17.96 ± 4.48	
Deceleration (n°)	11.36 ± 2.65	
Equivalent distance (m)	1957.98 ± 320.29	
Walking (m)	891.62 ± 135.21	
Low intensity running (m)	727.31 ± 148.25	
Moderate intensity running (m)	111.27 ± 43.39	0.02*
High intensity running (m)	3.25 ± 3.82	0.001*
Sprint running (m)	0	
Distance low-power (m)	1480.46 ± 236.48	
Distance high-power (m)	199.45 ± 49.56	0.03#
Distance very high-power (m)	46.13 ± 14.25	0.02#
Distance maximum power (m)	7.43 ± 6.57	0.001#

Discussion

The primary study purpose to determine the internal and external match demands of young beach soccer players during an official match. The secondary purpose was to understand the extent to which the demands of the beach soccer competition deviate from those of 11-a-side soccer.

A growing research focus in soccer suggest benefits of sand training on performance (Larsen et al., 2021; Costa et al., 2022; Pereira et al., 2021; Rago et al., 2019; Sannicandro et al., 2023; Cetolin et al., 2021). However, there is a lack of evidence on internal and external demands of young beach soccer players during an official beach soccer match.

Furthermore, it is currently unknown the extent to which the demands of the beach soccer competition deviate from those of 11-a-side soccer. The purpose of this study was to fill this gap. The internal load values obtained show that the beach soccer competition imposes high cardio-vascular intensity on the young soccer player: about 70% of the distance covered results in a HR value between 80% and 100% of HRmax, with an average HR of about 95% of HRmax. The intensity recorded in the HR is confirmed by the RPE value recorded at the end of the race.

When comparing these values with what is detected in young soccer players of the same age in 11-a-side soccer and in drills used in soccer, it emerges that the official beach soccer competition imposes a higher internal load than in 11-a-side soccer; it is superimposed on what is detected in small-sided 3vs3 games that reach %HR close to 90% (Custódio et al., 2022; Ashçı, 2016).

The metabolic power assessment approach allows for more accurate estimation of the energy expenditure of soccer players and considers accelerations, decelerations, instantaneous running speed and mechanical parameters of the young soccer player (Strauss et al., 2019; Darbellay et al., 2020).

The study analysis showed that in beach soccer the young soccer player travels most of the distance at low metabolic power. This value seems to suggest a modest mechanical load on the sand probably determined by moderate changes in speed during the official match: this hypothesis is supported by the values for accelerations (17.96 ± 4.48) and decelerations (11.36 ± 2.65), which are very slight. The comparison between 11-a-side soccer and beach soccer also emerges for this variable: in fact, metabolic power values are far lower than observed in

11-a-side soccer with players of the same age (Darbellay et al., 2020), where conventional surfaces allow relevant positive and negative velocity variations in relation to the larger size of the space and the demands of the performance model (Darbellay et al., 2020).

Moreover, in beach soccer, decelerations are not only ensured by neuromuscular behaviour but are favoured by the surface that accommodates braking by displacing sand grains and, in fact, reducing mechanical load.

The high energy expenditure observed in competition and the prevalence of distances covered in low-intensity walking and running might appear contradictory: however, the literature points out that sand determines an alteration in the biomechanics of running even at low intensity (McCrory et al., 2012; Gaudino et al., 2013.).

This alteration could explain why Average Metabolic Power (AMP) values are relevant: this finding is in accordance with previous studies that have observed that sand determines even at low speed a higher energy cost (about 24%) than a conventional surface (Zamparo et al., 1992). In fact, it is precisely the characteristic of sand, which creates small but numerous air voids beneath the surface, that causes the surface to be displaced and compressed during both foot strike and propulsive thrust (Gaudino et al., 2013).

Consequently, lower limb muscles need to exert additional effort to stabilize the point of force application on the surface immediately after the foot has slipped and sunk into the sand (Sanchez-Sanchez et al., 2020; Gaudino et al., 2013; Lejeune et al., 1998).

Furthermore, it should be noted that the increased energy expenditure, compared with running on harder surfaces, such as grass and asphalt, is favoured by the reduced elastic re-use because sand does not return the force impressed on the ground, dispersing it in heat (Giatsis et al., 2022). The lack of elastic reuse must therefore be compensated by additional muscle work and increased contact times (Giatsis et al., 2022).

The limitation of elastic reuse is also described in a recent review that compared sprint performance on sand and natural grass, pointing out that the soft surface results in increased running time on both 10- and 20-meter sprints (Sanchez-Sanchez et al., 2020).

This particular characteristic of sand is highlighted in the literature with young beach soccer players of the same age: the comparison between two-legs jumping performed on grass and on sand returned a decrease of about 23% (Sannicandro et al., 2023); while the comparison between one-leg jumping performed on the same surfaces described a decrease between about 27 and 33% (Sannicandro et al., 2023). The performance deficits obtained in movements requiring the use of the stretch-shortening cycle and observed on sand confirm what was found in this study on speed peak and high intensity running values: they are lower than those observed in 11-a-side soccer on natural and artificial grass (Al Haddad et al., 2015). Specifically, speed peak values observed in official matches on natural or artificial turf with young soccer players of the same age are from 25% (Bucheit et al., 2010) to 35%-38% (Al Haddad et al., 2015; Silva et al., 2022) higher than those observed in beach soccer.

According to the values observed in the study, the performance profile of the young beach soccer player shows very high internal load values that are higher than those of 11-a-side soccer. In contrast, the values for external load describe a very specific picture for this sport that differs significantly from 11-a-side soccer (Esposito & Raiola, 2020). Moreover, this framework induces the young beach soccer player to identify different movement and kicking strategies to adapt to the surface characteristics, compared to what occurs in 11-a-side soccer (Silva et al., 2022; Ceruso et al., 2019; Esposito et al., 2020; Sannicandro & Raiola, 2021). When comparing the values for internal and external load, emerges a profile of a sport that stresses metabolic and cardio-respiratory aspects to a great extent and mechanical aspects to a minimal extent.

Conclusions

The beach soccer characteristics seem to configure youth beach soccer as a functional sport activity for the characteristics of young soccer players. For these reasons, the modest stresses on external load variables allow beach soccer to be identified as an activity that can reduce the risk of injury in season and pre-season. Further studies could investigate whether there are differences in the various phases of the season: adaptations due to the particular sand characteristics could show differences in performance between the first and last phases of the competitive season.

Finally, considering that the Under-17 is the last youth category before transitioning into national beach soccer, analysis of internal and external load may provide additional information from comparison with values obtained in the top national league. This comparison could be useful for technical staffs to understand on which motor skills they should direct their training scheduling in the young beach soccer player training.

Conflict of interest

The authors declare no conflict of interest

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