Differences in internal and external load between adult and youth soccer players in a friendly match

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Summary

Objective: To determine differences in internal and external load during an unofficial match between First Division Adult and U-19 players of the same club using portable global positioning systems.
Methods: During an unofficial match between an adult and a U-19 category, internal load through heart rate and external load through running performance were monitored. Seven adult players (25.57 ± 5.06 years) and five U-19 players (18.6 ± 0.54 years) were monitored. Comparisons were made between categories in the first half, second half and total match using the Mann-Whitney U test and calculating effect sizes through percent difference (PD).
Results: Differences were found ($p<0.05$) of external load in maximum speed in first half and total match, with U-19 players reaching the highest values (maximum speed first half: 32.34 vs 27.77 km/h and PD = 15.3%; total match: 32.6 vs 28.14 km/h and PD = 14.7%). On the other hand, differences in internal load were only found in heart rate zone 3 (70 to 80% of maximum HR) in the first and second half, where U-19 players spent more time in this zone (heart rate zone 3 first half: 6.1 vs 1.73 minutes and PD = 111.6%; second half: 20.49 vs 5.21 minutes and PD = 118.8%). No differences were found in the other variables analyzed.
Conclusion: From the results obtained we can conclude that there are no differences in internal and external load in adult players with U-19 players, except for maximum speed and heart rate zone 3 in this team during a non-official match. Therefore, for practical purposes, the U-19 players of this team could be in conditions to face the physical demands required by the adult category competition.

Key words:
Sports. Heart rate. Soccer. Physiologic monitoring.

Diferencias de carga interna y externa entre futbolistas adultos y juveniles en un partido amistoso

Resumen

Objetivo: Determinar diferencias de carga interna y externa durante un partido no-oficial entre jugadores de Primera División Adultos y Sub-19 del mismo club empleando sistemas portátiles de posicionamiento global.
Método: Durante un partido no-oficial entre una categoría Adulta y una Sub-19, se monitoreó la carga interna a través de la frecuencia cardíaca y carga externa a través del rendimiento de carrera. Se monitorearon a siete jugadores adultos (25,57 ± 5,06 años) y cinco jugadores Sub-19 (18,6 ± 0,54 años). Se realizaron comparaciones entre las categorías en el primer tiempo, segundo tiempo y partido total mediante la prueba U de Mann-Whitney y calculando los tamaños del efecto a través de porcentajes de diferencia (PD).
Resultados: Se encontraron diferencias ($p<0,05$) de carga externa en velocidad máxima en primer tiempo y partido total, alcanzando los jugadores Sub-19 los valores más elevados (velocidad máxima primer tiempo: 32,34 *vs* 27,77 km/h y PD = 15,3%; partido total: 32,6 vs 28,14 km/h y PD = 14,7%). Por otro lado, solo se hallaron diferencias en carga interna en zona 3 de frecuencia cardíaca (70 a 80% de la FC máxima) en primer y segundo tiempo, donde los jugadores Sub-19 pasaron más tiempo en esta zona (zona 3 de frecuencia cardiaca primer tiempo: 6,1 *vs* 1,73 minutos y PD = 111,6%; segundo tiempo: 20,49 *vs* 5,21 minutos y PD = 118,8%). No se hallaron diferencias en las demás variables analizadas.
Conclusión: A partir de los resultados obtenidos podemos concluir que no existen diferencias de carga interna y externa en jugadores adultos con jugadores sub-19, con excepción de velocidad máxima y zona 3 de frecuencia cardiaca en este equipo durante un partido no oficial. Por lo que, para efectos prácticos, los jugadores Sub-19 de este equipo, podrían encontrarse en condiciones para enfrentar las exigencias físicas que requiere la competencia de categoría adulta.

Palabras clave:
Deportes. Frecuencia cardiaca. Fútbol. Monitoreo fisiológico.

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Introduction

Soccer is an intermittent sport in which high intensity action and rest periods alternate[1,2]. In recent decades, the competitive aspects of soccer have evolved[3], which is why greater emphasis has been placed on the development of players' physical qualities, this factor being considered the basis for their technical and tactical training[4]. Physical load can be described as external load (EL) (e.g. total distance, sprint distance, etc.) and acute responses which occur as a result of training or a match, also called internal load (IL) (e.g. heart rate, lactate, etc.)[5], and technical teams spend considerable time monitoring the physical load their players endure[6]. Research can be found in the scientific literature which provides varied information regarding the IL and EL of players in different categories and of different ages[7,8]. The growing interest in analysing IL and EL over the 90 minutes of a match is justified by the need for players to adapt to the multifactorial physical demands of a game[9], understanding that their technical and tactical performance relies on their physical performance[10]. The identification of the IL involved in soccer reveals essential information which can help improve players' training and recovery strategies[11], and also determine the onset of fatigue[12–14].

Methods based on measuring the heart rate (HR) in training or competition have been used to assess IL[6]. Alexandre *et al*. (2012)[11] state that HR constitutes one of the physiological variables most used to quantify the IL of soccer players. It allows us to determine when players' performance drops and when fatigue sets in[14]. Mean exercise intensity has been reported to range from 80 to 90% of maximum heart rate (HRmax)[11].

With regard to EL, information can be found on the movements made by soccer players, where it has been established that the distance covered (DT), regardless of the players' level of perfection, ranges from 9 to 14 km per game[2,15]. Another measurement which indicates players' athletic performance is variation in the speed of movements during a game[16]. It has been reported that during matches soccer players run 22-24% of the time at speeds over 15 km/h (high intensity threshold; corresponding to the speed above mean speed at the second ventilatory threshold in professional soccer players), 8-9% at more than 20 km/h (very high intensity threshold; corresponding to the speed above mean maximal aerobic speed in professional soccer players), and 2-3% at over 25 km/h (sprint threshold; corresponding to the closing speed at maximum sprint speed when professional soccer players run)[17].

This information makes it possible to quantify players' work-rate profiles, helping coaches identify their players' performance[18]. Studies show that speed or sprint actions are carried out frequently during soccer matches [2,19]. The ability to sprint repeatedly throughout a game allows us to distinguish different performance levels in players[20]. This indicator can be analysed by determining the total number of sprints, the distance covered or the duration of high-speed activity registered by the players[21]. In this way, it is possible to understand empirically that high-speed efforts in a soccer match are not stable properties and that they depend on factors such as the physical condition of the player, environmental conditions and the tactical functions of the players[16,22].

The use of technology by means of satellite location systems (GPS) means researchers can evaluate EL and IL in intermittent high-intensity team sports, monitoring, assessing and controlling athletic performance[23,24]. The development of specific recording instruments for team sports has provided an essential tool to learn more about the activity patterns of these disciplines and for the quantification of training loads[25]. This technology has also been applied to detect the onset of fatigue in matches and identify the most intense periods of play and different activity profiles by position, level of competition and sport[12,26]. The importance of quantifying the exertion load in soccer contributes to a better understanding of the specific physical and physiological demands of the sport and opens the way to optimising athletic performance in the game[21].

To our knowledge, IL and EL match data are not available between the adult and under-19 categories, so having them could help coaching teams make decisions from a conditional perspective when it comes to identifying whether youth players are prepared to face the adult category and even to see if they are ready to join it. The objective of this research was to assess the IL and EL of players in a professional Chilean first division team in real game conditions during an unofficial match and determine the differences between the adult and under-19 categories of the same club using GPS.

Materials and method

Design

This research took a quantitative, non-experimental, cross-sectional and descriptive approach.

Description of the sample

The sample consisted of 12 soccer players, 7 adult professionals (25.57 ± 5.06 years old) and five under-19 players, (18.6 ± 0.54 years old) belonging to a professional soccer club (Table 1), who competed in the Chilean national championship in the first division adult and youth categories. All the participants were informed of the study's objectives and voluntary nature through informed consent according to the Declaration of Helsinki (2013)[27]. These documents were read and signed by each of the participants. Authorisation was also requested from the bodies responsible for the club.

Procedures

The assessment of IL in this study was conducted using heart rate parameters, while EL was assessed using variables of total distance covered, speed and number of sprints. The data used for the study were from players who took part throughout the match. Warm-up data were not included in the match load. The match was played on a natural

Table 1. Characteristics of the sample.

Category	n	Age M ±SD	Height (m) M ±SD	BM (kg) M ±SD	BMI M ±SD
Adults	7	25.57 ±5.06	1.74 ±0.06	71 ±4.97	23.47 ±0.63
Under-19	5	18.6 ±0.54	1.77 ±0.02	72.38 ±2.61	22.82 ±1.15

M: mean; SD: standard deviation; n: sample number; BM, body mass; BMI: body mass index.

grass pitch using studded boots. The match took place at 10 a.m. and respected official match times: 2 halves of 45 minutes with a halftime break of 15 minutes.

Instruments and materials

The SPI elite GPS system, designed and developed by the Australian company GPSports Systems[28]. This device is capable of recording athletes' movements, speeds and heart rate. The SPI elite has the following characteristics: GPS (sampling frequency: 1 Hz), heart rate monitor, triaxial accelerometer, dimensions of 91mm x 45mm x 21mm and a weight of 75g. When the player's performance is captured by the SPI elite, the data is downloaded to a computer to be analysed and handled using the TEAM AMS software designed by the company GPSports Systems, a programme which generates reports via spreadsheets.

The assessment of the players' EL was determined on the basis of proposals found in the scientific literature in order to make possible comparisons. The distance covered was quantified in the five speed intensities established by Di Salvo *et al.* (2007)[29]: $D_{1\text{-}11}$ (0 to 11 km/h standing, walking or jogging), $D_{11\text{-}14}$ (11.1 to 14 km/h low-speed running), $D_{14\text{-}19}$ (14.1 to 19 km/h moderate-speed running), $D_{19\text{-}23}$ (19.1 to 23 km/h high-speed running) and D_{23} (>23 km/h sprinting). The total distance covered (TD) and the maximum speed reached during the match (MS) were also calculated.

IL was measured using the heart rate recorded. It was classified into the six activity zones established by Cunniffe *et al.* (2009) based on the maximum heart rate reached during the match (HRmax) (30): Zone 1 (HR1) (0 to 60% HRmax), zone 2 (HR2) (60 to 70% HRmax), zone 3 (HR3) (70 to 80% HRmax), zone 4 (HR4) (80 to 90% HRmax), zone 5 (HR5) (90 to 95% HRmax) and zone 6 (HR6) (95 to 100% HRmax). The mean heart rate during the match (MHR) was also calculated.

Statistical analysis

The descriptive statistics of the data were presented as mean and standard deviation. The Shapiro-Wilk normality test was used to discover the data distribution, and Levene's test was used to assess homoscedasticity. A non-normal distribution of variables was verified, and their homoscedasticity was accepted. The nonparametric Mann–Whitney U test for independent samples was applied to determine whether there were differences between groups. Effect size was calculated via the percentage difference (PD) between categories[31]. All the statistics were processed with SPSS v.25 software with an alpha of $p<0.05$.

Results

Tables 2 and 3 show the description of IL and EL in the first half (T1), second half (T2) and total match (TM) split into the adult and U19 categories. It can be observed that differences ($p<0.05$) were only found in EL in the MS variable in T1 and TM, the U19 players reaching the highest values (T1-MS: 32.34 vs 27.77 km/h and PD = 15.3%; TM-MS: 32.6 vs 28.14 km/h and PD = 14.7%). Meanwhile, differences were only found in IL in the HR3 variable in T1 and T2, with the U19 players spending more time in this zone (T1-HR3: 6.1 vs 1.73 minutes and PD = 111.6%; T2-HR3: 20.49 vs 5.21 minutes and PD = 118.8%). No differences were found in the other variables analysed.

Discussion

GPS is a useful tool to control and understand the specific physical demands of this sport and thus contribute to the design and planning of training to optimise players' performance in competitions (25). This study aimed to assess and discover differences in internal load (IL) and external load (EL) between adult and youth soccer players in a friendly match using portable GPS devices. Its main findings were differences in EL in the MS variable in T1 and TM, the U19 players reaching the highest values. Differences were also found in IL in the HR3 variable in T1 and T2, with the U19 players spending more time in this zone.

That no differences were found in the other IL and EL variables can be explained by the physical condition of each category and the training loads (IL and EL during the week) to which they may have been subjected during the season. Rabbani *et al.* (2021)[32] compared the adult category (age: 28.3 ±2.0 years old) with the U19 category (age: 18.0 ±0.4 years) of a first division team in Iran in tests of acceleration (time 0 to 10 metres), speed (time 0 to 30 metres), change of direction (505 test) and intermittent fitness (30-15 IFT), and IL was assessed indirectly through rate of perceived exertion (RPE), finding that adult players performed better in acceleration tests (Effect size [ES]= 0.96), speed (ES=0.81) and change of direction (ES=0.24), but U19 players performed better in terms of intermittent fitness (ES=0.34). In turn, the U19 players had higher RPEs than the adult category, except during matches, where only trivial differences were found. Another study found similar results regarding training load, where the EL of an adult team (age: 25.9 ±5.2 years old) was compared with that of the U19 category (age: 18.7 ±1.3 years old) of a French second division team over a season, and it was found that the loads were similar and that, for some variables, the values registered in the U19 category were actually higher[33]. Assuming that training loads cannot be the same in different clubs, something similar could occur in our study and explain why there are no significant differences in most of the EL and IL variables.

Table 2. Descriptive and inferential statistics of the first and second halves.

Variables	1st Half						2nd Half					
	Adult		U19		Inter-groups		Adult		U19		Inter-groups	
	M	±SD	M	±SD	p	PD	M	±SD	M	±SD	p	PD
External load												
TD (m)	5480	208	5275	409	0.37	3.8	4866	738	4990	464	0.68	2.5
MS (km/h)	**27.7**	**2.3**	**32.3**	**2.5**	**0.02***	**15.3**	26.2	3.1	27.9	1.5	0.28	6.3
D1-11 (m)	3399	146	3322	190	0.68	2.3	3104	383	3260	179	0.46	4.9
D11-14 (m)	943	161	788	18	0.22	17.9	807	164	698	167	0.16	14.5
D14-19 (m)	792	167	769	140	0.46	2.9	707	143	685	200	0.37	3.2
D19-23 (m)	241	61	259	75	0.93	7.2	181	73	254	95	0.37	33.3
D23 (m)	104	69	134	61	0.46	25.2	67	58	91	50	0.37	30.4
NS (frequency)	6.4	2.7	7.8	3	0.41	19.7	5	4.1	7	2.9	0.36	33.3
Internal load												
MHR (ppm)	168	51	180	13	0.8	6.9	154	44	170	12	0.46	9.9
HRmax (ppm)	190	45	207	11	0.74	8.6	185	53	202	11	0.93	8.8
HR1 (min)	3.1	8	0.1	0.2	0.69	187.5	3.9	9.7	0.2	0.3	0.6	180.5
HR2 (min)	3.4	8.3	0.5	0.6	0.89	148.7	0.9	0.9	2.5	2.5	0.22	94.1
HR3 (min)	**1.73**	**1.9**	**6.1**	**3.4**	**0.02***	**111.6**	**5.2**	**5.3**	**20.4**	**22.2**	**0.04***	**118.8**
HR4 (min)	12.6	9.2	19.8	2.1	0.08	44.4	14.2	8.1	18.7	4.4	0.46	27.6
HR5 (min)	15.5	7.9	14.2	3.9	0.22	8.8	14.9	12.3	10.2	3.5	0.46	37.7
HR6 (min)	8.3	6.3	4.1	1.1	0.29	67.7	5.72	4.8	3.4	2.9	0.46	50.9

*differences <0.05; M: mean; SD: standard deviation; PD: percentage difference; TD: total distance; MS: maximum speed; D1-11 total distance 1-11 km/h; D11-14 total distance 11-14 km/h; D14-19 total distance 14-19 km/h; D19-23 total distance 19-23 km/h; D23 total distance over 23 km/h; NS: number of sprints; MHR: mean heart rate; HRmax: maximum heart rate; HR1 time in heart rate zone 1; HR2 time in heart rate zone 2; HR3 time in heart rate zone 3; HR4 time in heart rate zone 4; HR5 time in heart rate zone 5; HR6 time in heart rate zone 6.

The MS values obtained by the U19 category were similar in the study by Hespanhol *et al.* (2021)[34], who related body composition and states of biological maturation with maximum speed reached during a soccer match, finding that more biologically developed players, post peak height velocity (PHV), had higher MS (32.22 ±1.79 km/h) than players pre-PHV (21.91±2.56 km/h) and at PHV (29.77 ±2.16 km/h), which may be consistent with the age range of our sample. In turn, Zúñiga-Morales *et al*. (2021)[35] reported mean maximum speed values of 28.4 ±2.5 to 29 ±2.3 km/h in professional players belonging to a Costa Rican first division club during 5 pre-season friendly matches, reporting values slightly higher than those obtained by the professional squad, although it should be taken into account that, in this case, the players were only assessed once and against a youth team. However, the values obtained by the professional players in our study are similar to those found by Mallo *et al*. (2015)[36], who reported a mean maximum running speed of 28.3 ± 2.5 km/h in professional soccer players in Spain during 11 pre-season friendly matches. There is a decrease in DT of 5% during the second half reported by Krustup, *et al*. (2001)[37] and of 3% according to Mohr *et al*. (2003)[38], similar to those found in both categories.

The HR zones proposed by Cunniffe *et al*. (2009)[30] show that the U19 players spent more time in HR3 (6.1 vs 1.73 and 20.49 vs 5.21), but no differences were reflected in the distances in any specific speed range, so these differences could be attributed to the different positions in which the players play[39], performance fatigability or the perceived fatigability with which they arrived at the match[40,41]. In Vargas *et al.* (2014)[42], MHR values of 165.85±14.88 ppm and HRmax of 189.25 ±5.96 ppm were recorded during pre-season matches, which are similar to those obtained by the professional players but lower than those recorded by the U19 players in our study. The MHR values are 88.4% and 86.9% of HRmax, which are higher than those recorded by Stølen *et al*. (2005)[10] in elite players. This would imply that age and competitive level may be a differentiating factor in physical performance [43].

Regarding the results obtained, we recognise limitations in our study, mainly referring to the sample size, which only includes two soccer teams, which are different categories in the same club, so it is not possible to generalise the values reported in this study to other teams of the same competitive level, It should also be noted that the data were collected during a single unofficial match, and different responses in the variables studied might be expected in an official match, where the values and differences between groups might increase due to the intrinsic motivation of competition and tactical behaviour[39,44]. Playing position should also be considered in the analysis, because the

Table 3. Descriptive and inferential statistics of the total match.

Variables	Adult		Under-19		Inter-groups	
	M	±SD	M	±SD	p	PD
External load						
TD (m)	10347	671.9	10265	813	0.465	0.8
MS (km/h)	**28.14**	**2.27**	**32.6**	**2.41**	**0.018***	**14.7**
D1-11 (m)	6502	502.9	6582	345.5	0.935	1.2
D11-14 (m)	1751	196.6	1488	320.1	0.167	16.3
D14-19 (m)	1499	171.7	1455	340.6	0.372	3.0
D19-23 (m)	422.7	97.83	514	154.3	0.372	19.5
D23 (m)	171.1	109.9	225.4	86.01	0.167	27.4
NS (frequency)	11.43	5.83	14.8	5.22	0.188	25.7
Internal load						
MHR (ppm)	161.1	46.89	175.6	12.94	0.685	8.6
HRmax (ppm)	191.7	45.94	207.4	11.5	0.745	7.9
HR1 (min)	7.11	12.1	0.33	0.46	0.603	182.3
HR2 (min)	4.37	7.97	3.12	3.19	0.935	33.4
HR3 (min)	6.94	7.05	14.6	8.11	0.123	71.1
HR4 (min)	26.81	16.41	38.59	5.71	0.167	36.0
HR5 (min)	30.53	9.26	24.53	6.67	0.167	21.8
HR6 (min)	14.04	10.49	7.64	2.98	0.291	59.0

*differences <0.05; M: mean; SD: standard deviation; PD: percentage difference; TD: total distance; MS: maximum speed; D1-11 total distance 1-11 km/h; D11-14 total distance 11-14 km/h; D14-19 total distance 14-19 km/h; D19-23 total distance 19-23 km/h; D23 total distance over 23 km/h; NS: number of sprints; MHR: mean heart rate; HRmax: maximum heart rate; HR1 time in heart rate zone 1; HR2 time in heart rate zone 2; HR3 time in heart rate zone 3; HR4 time in heart rate zone 4; HR5 time in heart rate zone 5; HR6 time in heart rate zone 6.

physiological response shown through IL and EL is related to the characteristics and specific requirements of the position[39,43]. The results and analysis of this study do not permit any explanation of the performance of a team because technical and tactical factors, and the internal logic of the game are not taken into consideration, it only being possible to provide a vision of the conditional and individual aspects of the players[45].

Considering the limitations of the study, it has been possible to compare the physical profiles of soccer players during an unofficial match and to see the degree to which the variables studied manifested themselves during the game for different competitive categories. The data presented in this study, which focuses on a sample of Chilean athletes, aims to serve as an aid for coaching teams by allowing them to make plans based on the physical demands of the game in the different categories and to fill the research gap faced by Chilean soccer in this field, contributing to the collection of data which could benefit the sports performance of teams and making the information recorded available to portray the reality of soccer players in the national sporting landscape, opening the way to future research to favour the different participants in this sport.

Conclusion

From the results obtained, we can conclude that there are no differences in internal and external load between adult and under-19 players, with the exception of MS and HR3, during an unofficial match. Therefore, for practical purposes, the U19 players in this team could be in a position to meet the physical demands that competition in the adult category requires. Finally, due to the low number of participants and data collection over time (longitudinal), it is necessary to continue research to corroborate and confirm these results in other teams.

Contributions of the authors

J.P-C: Design, analysis and composition of the manuscript; S.E-M: Design, data collection and composition of the manuscript; R. V-V: Composition of the manuscript; E.A-M: Analysis, data collection and composition of the manuscript; B.M: Analysis and composition of the manuscript; P.M-M: Design, analysis and composition of the manuscript.

Conflict of interest

The authors declare that they are not subject to any type of conflict of interest.

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