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Research article

Effect of Court Dimensions on Players' External and Internal Load during Small-Sided Handball Games

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Abstract
The aim of this study was to investigate the effect of three different court dimensions on the internal and external load during small-sided handball games. Six male amateur handball players took part in this study and participated in three different 8-min 3vs3 (plus goalkeepers) small-sided handball games (each repeated twice). The three court dimensions were 12×24m, 30×15m and 32×16m. Through Global Positioning System devices (SPI pro elite 15Hz, GPSports) and video analysis, the following parameters were recorded: cyclic and acyclic movements (distance covered and number of technical actions executed), heart rate, and rating of perceived exertion (RPE). Total distance travelled increased with court dimensions (885.2m ± 66.6m in 24×12m; 980.0m ± 73.4m in 30×15m; 1095.0m ± 112.9m in 32×16m, $p < 0.05$). The analysis of distance covered in the four speed zones (0–1.4 $m \cdot s^{-1}$; 1.4–3.4 $m \cdot s^{-1}$; 3.4–5.2 $m \cdot s^{-1}$; >5.2 $m \cdot s^{-1}$) highlighted substantial differences: playing with the 30×15m court in comparison to the 24×12m, the players covered less distance in the first speed zone ($p = 0.012$; ES = 0.70) and more distance in the second ($p = 0.049$; ES = 0.73) and third ($p = 0.012$; ES = 0.51) speed zones. Statistical differences were also found between the 24×12m and 32×16m courts: the players covered more distance in the second and third speed zones ($p = 0.013$, ES = 0.76; $p = 0.023$ ES = 0.69) with the 32×16m court in comparison to the 24×12m. There was no significant effect of court dimensions on the technical parameters (number of team actions, passes, piston movements toward goal and defensive activities), the number of specific handball jumps and changes of direction, and the time spent in the different heart rate zones. Considering the average data of all the experimental conditions together (24×12m, 30×15m, 32×16m), a pronounced statistical difference was highlighted between the values in first two HR zones and the last two ($p < 0.05$; large ES). The rating of perceived exertion was significantly higher during the drill with the 32×16m court compared with the 24×12m one ($p < 0.05$; ES = 2.34). Our findings indicate that changing court dimensions during small-sided handball games can be used to manipulate both external and internal loads on the players.

Key words: Handball; sport-specific training; video analysis; Global Positioning System (GPS).

Introduction

Handball is a team sport with two opposing teams, which alternately take the role of either attacker or defender, depending on who has possession of the ball. The work-rate intensity and volume of the external load in handball are highly heterogeneous. During games, players are exposed to both high- and low-level intensities of external load. External load in handball can be divided into acyclic and cyclic activities. In a match, acyclic activities (e.g., passing the ball, various kind of shots, jumps, body contacts, falls) occur along with the player's cyclic movements (running, walking, jogging, cruising, and moving sideways or backwards) (Sibila et al., 2004). Data on cyclic movements show a greater distance travelled for the wings, with a higher percentage of time spent sprinting (running speed above 5.2 $m \cdot s^{-1}$); this trend was also confirmed during 2×20 minute matches (Sibila et al., 2004). Other studies, utilizing time-motion analysis, revealed significant differences in the total distance travelled (Bon, 2001; Luig et al., 2008). Differences in acyclic activities are also apparent among the players with different playing positions: significantly more passes and shots are executed by the back players compared with others (Pori et al., 2009). In order to evaluate the internal load in handball, the most frequently used methods are analyses of heart rate (HR) and blood lactate concentrations (LA). Average HR during official matches has been reported to be approximately 82% of maximal HR (HRmax) (Povoas et al., 2012). Blood lactate ranges between 2 and 6 $mmol \cdot l^{-1}$ (Pori et al., 2007).

To cover the specific game demands, more specific training methodologies have been developed. Following these developments, several authors have now focused their attention on investigating physiological and technical activities of specific drills. For example, when many games were investigated, these drills were performed with different court dimensions and number of players (Abrantes et al., 2012; Aroso et al., 2004; Da Silva et al., 2011; Dellal et al., 2011; Gabbett et al., 2012; Hill-Haas et al., 2011; Jones and Drust, 2007; Katis and Kellis, 2009; Kelly and Drust, 2009; Kennett et al., 2012; Köklü et al., 2011; Rampinini et al., 2007; Tessitore et al., 2006) and different duration (Fanchini et al., 2011; Hill-Haas et al., 2011; Tessitore et al., 2006). In particular, the main question of several studies in different team sports was whether exercises performed with the ball can be used as a substitute of traditional training methods without the ball (Hill-Haas et al., 2011; Impellizzeri et al., 2006; Kelly et al., 2013; Little and Williams, 2006; Sassi et al., 2004).

Compared with generic training methods, those reproducing specific game situations may provide a useful conditioning stimulus, together with technical and tactical training components (Hill-Haas et al., 2011; Impellizzeri et al., 2006; Sassi et al., 2004). In handball, there is a lack of scientific knowledge about how to set up small-sided

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games (SSGs), in terms of the number of players involved, court dimensions, and duration. In spite of substantial growth in research related to specific training methods in many team sports, only two studies on SSGs in handball have been published (Buchheit et al., 2009a; 2009b). The first study of Buchheit et al. (2009a) compared a traditional intermittent running exercise with a specific four-a-side drill played on a regular court dimension, reporting greater time spent close to maximal oxygen update, lower HR and blood lactate levels, and a similar rating of perceived exertion (RPE) during the handball-specific condition. The second study of Buchheit et al. (2009b) highlighted the improvement of repeated sprint ability (RSA) and high-intensity intermittent running performance in young players (as measured by 30-15 Intermittent Fitness Test) following both high-intensity interval training and specific game-based handball training. While both methods were equivalent to improve most of the performance test measures, SSGs could be preferred due to their greater specificity. However, only one type of SGG (i.e. 4vs4 on the entire handball court) was used during these two studies. Whether the variations in player numbers and court dimensions could be as efficient at developing physical performance is presently unknown.

Beside the data about metabolic response of the players, during the SSGs, researchers also attempt to obtain data about cyclic activities (e.g., running and walking with different intensity) and acyclic activities (e.g., jumps, shots, passes, changes of directions) performed during the game. With this purpose, a wide range of different measurement methods of notational and time motion analysis were introduced. In this field, the introduction of GPS technology has been a significant innovation. In recent years, GPS systems have been adopted to track time-motion characteristics for all kind of games (Brewer et al., 2010; Castellano and Casamichana, 2010; Macutkiewicz and Sunderland, 2011).

The aim of this study was to investigate the effect of three different court dimensions on the internal load (assessed by heart rate and rate of perceived exertion) and external load (assessed by running intensity and the number of technical actions) during SSGs in handball. Based on previous studies in soccer (Casamichana and Castellano, 2010; Rampinini et al. 2007), we expected to observe both greater internal and external loads when increasing the court dimensions.

Methods

Sample

Six amateur players (age 28±3 years, range 24–33 years) belonging to an Italian Serie A1 league team (second tier championship in Europe) were recruited to participate in this study. Players had at least six years of experience in handball training (four times per-week) and competitions; they also took part in national championships at the time of the investigation. Participants were volunteers and took part in the present study after giving their written consent. All of the procedures received the approval of the ethics committee of the Faculty of Sports, at the University of Ljubljana.

Methodology

Experimental procedures

Three court dimensions were used: 24×12m, 30×15m and 32×16m. For each court condition, an eight-minute drill of continuous exercise without substitutions was performed. This drill duration was chosen on the basis of previous studies (Buchheit et al., 2009a; Tessitore et al., 2006). Consistent verbal encouragement provided by the coach, to ensure the maintenance of a high work-rate, was allowed (Ramipinini et al., 2007).

The study was conducted over a 12-week period, with all experimental sessions scheduled at the same time of the day, (on a Tuesday once every two weeks during normal training) to avoid any effect of circadian rhythms on the measured variables (Drust et al., 2005). Before each experimental session, players wore a specific vest to support the GPS and heart rate devices, after which they performed a standardized 20-minute warm-up. During the SSGs, the defence in front of the goalkeeper was a zone-defence that reproduced the central part of a hypothetical 5-1 defence, with the centre back and two half defenders, and without the front centre defender. The opponent at the beginning of each action held the positions of left, right and central backcourts, independent of their real role. The rules of the drills were the same as for normal handball with the exceptions of:

1)throw-in after a goal was immediately made by the goalkeepers from their 6-m area, and the investigator was always available to immediately replace the ball when it was thrown out of the playing area (Buchheit et al., 2009a),

2)the 2-min exclusions were not present, but the referee only sanctioned "normal" faults.

The referee for all of the drills was always an official referee of the Italian handball federation.

External load

By means of a SPI pro elite GPS system 15hz (GPSports), the cyclic movements were categorized as: 1) total distance in the drills; 2) percentage of time spent from 0 to 1.4 $m \cdot s^{-1}$; 3) percentage of time spent between 1.4 $m \cdot s^{-1}$ and 3.4 $m \cdot s^{-1}$; 4) percentage of time spent between 3.4 $m \cdot s^{-1}$ and 5.2 $m \cdot s^{-1}$); 5) percentage of time spent above 5.2 $m \cdot s^{-1}$ (Pori et al., 2005; Šibila et al., 2004). The distance covered in each speed zone was also detected. There was no obstruction to the signal of the GPS device within the handball court, as it was merely covered by a plastic sheet. However, within the literature, the validity and reliability of this technology has been questioned (Duffield et al., 2010; Jennings et al., 2010; Petersen at al., 2009). The findings of these studies revealed that 1hz and 5hz GPS devices have acceptable levels of accuracy and reliability when measuring the total distance and peak speeds in high-intensity intermittent exercises. These may not provide reliable measures for higher intensity activities. With the aim of providing valuable information about acyclic activities, a time-motion analysis was applied. This analysis was done by a video camera positioned on one side of the pitch. The footage was then analysed to count the number of acyclic activities: shots to the goal, pistons movement towards the goal, passes, jumps, stopping attackers with body and arms (defensive activities), changes of direction, action per team. The pistons movement towards the goal is the basic attacking movement by moving continuously forwards and backwards (European Handball Federation, 2011). The action is defined as part of the game from the moment of coming into possession of the ball to the moment of losing the ball or scoring a goal (Rogulj et al., 2004).

Internal load

In order to assess the individual HRmax, players performed a 30-15 Intermittent Fitness Test (Buchheit, 2008; Buchheit et al., 2009c). The speed at the last fully completed stage was retained as VIFT. The maximal heart rate reached was considered as players' HRmax.

HR was collected during all SSGs. The individual minimum HR was noted (each morning in bed for five consecutive days), and this data, together with the maximum HR obtained at the end of the 30-15 Intermittent Fitness Test, was used in the Karvonen formula (HR(%)=[100*(HR-HRmin)]/[HRmax-HRmin]) to calculate the HR reserve (Duarte, R., et al., 2010). The reference scale was the following: <50%, 50%–70%, 70%–90% and >90% of the relative HR reserve. Next, the percentage of time spent in each HR zone was calculated for subsequent statistical analysis.

Statistical analysis

The statistical package SPSS (17.0) was used for the analysis. Data were presented as mean±SD, and the alpha level for significance was set at p≤ 0.05. A parametric statistical approach was chosen for continuous variables (total distance, percentage of time spent and distance in HR and speed zones, and RPE). The Kolmogorov test was first applied to confirm the normal distribution of the data. Two separate multivariate analyses of variance (MANOVA) for repeated-measures were applied. In the first MANOVA, the four HR zones were the dependent variables and the field dimensions the independent variable (within factor). In the same, way in the second MANOVA the four speed zones were the dependent variables, and the filed dimensions the independent variable (within factor). MANOVA was chosen because it offers several advantages in comparison to multiple univariate ANOVAs, including the ability to measure multiple facets of a problem, to improve power, and to reduce Type I error rates (Tabachnick and Fidell, 2001). Furthermore, two separate within-subjects repeated measures analysis of variance (ANOVA) were used to test for differences in the total distance covered and RPE values in each field dimension. To control for the assumptions that must be met in this kind of analysis, Mauchly's test for the sphericity was applied. When the sphericity assumption was violated, the Greenhouse-Geisser corrections were taken in account. In order to avoid Type I statistical errors, univariate effects within MANOVAs were examined only if the overall MANOVA was significant. When univariate effects were detected, multiple comparisons t-tests with Bonferroni corrections were used. A non-parametric (i.e. chi-square) approach was chosen for acyclic activities (i.e. number of events). To provide meaningful analysis for significant comparisons from small groups, in the parametric statistical approach, Cohen's d effect sizes (ES) between groups were also calculated. An ES < 0.2 was considered trivial, from 0.3 to 0.6 small, <1.2 moderate and >1.2 large (Hopkins, 2006). Instead, to provide meaningful analysis for comparisons from small groups for variables that have required a non-parametric approach (i.e. chi-square), the phi effect sizes between groups were also calculated, considering 0.1, 0.3, 0.5 as small, medium and large effect sizes, respectively (Huck, 2000)

Results

The results concerning cyclic movements are presented in Table 1. The total distance travelled by players during SSGs increased significantly in parallel with the increasing dimensions of the court (p < 0.05; large ES).

Table 1. Total distances covered in each experimental condition. Data are means (±SD).

	Total distances (m)
24x12m	885.2 (66.7)
30x15m	980.0 (73.5) *
32x16m	1095.0 (113.0) *†

* = Significant difference vs. 24x12m (p < 0.05; large ES)
† = Significant difference vs. 30x15m (p < 0.05; large ES)

The results of distance covered by players in the four speed zones are reported in Table 2. Statistical analysis highlighted substantial differences between the 24×12m and the 30×15m court in the first (p = 0.012; ES = 0.70), second (p = 0.049; ES = 0.73) and third (p = 0.012; ES = 0.51) speed zones. With the 30×15m court, players covered more distance in the second and third speed zones compared with 24×12m court. However, players covered less distance in the first speed zone with the 30×15m court compared with the 24×12m one. Statistical differences were also found between the 24×12m and 32×16m court in the second and third speed zones (p = 0.013, ES = 0.76; p = 0.023 ES = 0.69): with the greatest pitch dimensions (32×16m), players covered more distance in the second and third speed zones in comparison to the smallest one (24×12m). There were no substantial differences in the fourth speed zone for all of the experimental conditions.

There was no significant effect of court dimension on acyclic activities (Table 3). Finally, there was no effect of court dimension on HR (Table 4).

Table 2. Distances covered in the four speed zones in each experimental condition. Data are means (±SD).

	1st speed zone (m)	2nd speed zone (m)	3rd speed zone (m)	4th speed zone (m)
24x12m	267.0 (25.0)	526.7 (30.8)	85.2 (46.1)	.4 (1.0)
30x15m	219.9 (22.7) *	633.9 (65.0) *	155.5 (71.0) *	6.2 (11.1)
32x16m	230.0 (30.5)	669.8 (80.4) *	205.8 (77.5) *	27.9 (35.9)

* = Significant difference vs. relative 24x12m (p < 0.05; moderate ES).

Table 3. Acyclic activities in each experimental condition. Data are means (±SD).

	Actions	Shoots	Passes	SABA	PM	Jumps	COD
24x12m	34 (1)	58 (5)	71 (6)	15 (3)	8 (2)	11 (2)	7 (3)
30x15m	29 (1)	49 (3)	65 (6)	4 (1)	6 (1)	8 (2)	6 (3)
32x16m	28 (2)	48 (4)	72 (4)	6 (1)	3 (1)	8 (3)	4 (2)

SABA = Stopping attackers with body and arms; PM = Pistons movements toward goal; COD = Changes of direction; PM = Pistons movement toward goal; COD = Change of direction.

Table 4. Time spent in Heart Rate zones in each experimental condition. Data are means (±SD).

	<50% HRrel (% drill time)	50%-70% HRrel (% drill time)	70%-90% HRrel (% drill time)	>90% HRrel (% drill time)
24x12m	.6 (.9)	5.0 (4.4)	40.8 (27.4)	53.7 (31.6)
30x15m	2.7 (1.1)	9.5 (9.8)	65.1 (23.3)	22.7 (27.7)
32x16m	.6 (1.1)	3.4 (1.6)	47.1 (37.8)	48.9 (39.3)

The RPE values found during the 32×16m drill were significantly higher compared with the drill on the 24×12m court ($p < 0.05$; ES = 2.34). There was no other significant difference in RPE (Table 5).

Table 5. Rating of perceived exertion's values in each experimental condition. Data are means (±SD).

	RPE values
24x12m	6.3 (.5)
30x15m	7.7 (.8)
32x16m	8.2 (1.0) *

* = Significant difference vs. 24x12m ($p < 0.05$; large ES)

Discussion

The results from our study indicated that the size of the court affects external and internal loads during the handball SSGs. In general, almost all of the parameters increased in parallel with the increase in court dimensions. Moreover, our results can help us to describe the main characteristics of SSGs in handball, with respect to both external and internal loads.

The values of the total distance travelled during the games significantly differed between the 24×12m and 32×16m courts. Indeed, the distance covered by players increased parallel with the court dimension. As we expected, with the increasing of the court dimensions, there was also an increase of the cyclic activities. For the comparison of the present findings, we used the variable "distance covered per minute". The total distance covered per minute in our research was 110.7 $m \cdot min^{-1}$ in a game with a 24×12m court, 122.5 $m \cdot min^{-1}$ in a game with 30×15m court and 136.9 $m \cdot min^{-1}$ on the 32×16m court. These values are much higher than the values obtained in a match on normal handball court. The normal values vary from 79.8 $m \cdot min^{-1}$ (Bon, 2001) to 87.5 $m \cdot min^{-1}$. (Pori et al., 2009). However, our data is similar to the data obtained in the soccer SSGs (Barbero-Alvarez et al., 2007; Pereira et al., 2007). It is obvious that the short duration of the games and the reduced number of players in SSGs allow participants to perform a relatively high amount of cyclic movements in a short period. This kind of argument is also supported by the data obtained by Buchheit (Buchheit, et al., 2009a). Players covered in average 154 $m \cdot min^{-1}$ in the 4vs4 handball game on the regular court in 2×225sec periods. This means there was more space per player than there was in the previous research and, as a consequence, there was a greater amount of distance covered. As there were different match analysis systems being applied in these studies, any comparisons of the results should be done with caution (Randers et al., 2010).

When analysing cyclic movements divided into the four speed zones, we observed a small amount of fast running and sprinting, (in the highest speed zone). This might be due to the fact that with less space available for each player, players lack the possibility of accelerating and increasing their running speed; indeed, data regarding distance covered by the players in the 2nd and 3rd speed zones (run and fast run) has grown with the increasing of court dimensions (24×12m vs. 32×16m court) (Table 2). Similar data were reported also from a soccer SSGs study (Casamichana and Castellano, 2010).

We determined there were no statistical differences occurring among the acyclic activities, during games on all three court dimensions. However, even though not statistically significant, differences occurred in the number of stopping attackers with body and arms (defensive actions) (medium phi ES = 0.33). The greater occurrence of these actions was in the game with 24×12m court compared with the 32×16m court. As there was an increase in the defensive activities on a smaller SSGs court, this can be considered as a consequence of the smaller area per player, which causes a greater proximity to the opponents and hence higher probability for physical contact. In comparison with the data provided by Póvoas et al. (2012), during a normal handball game, our data revealed a higher number of jumps per minute [9 ± 2.9 (1.12/min) vs. 16.8 ± 6.14 (0.28/min)]. In soccer (Kelly and Drust, 2009; Tessitore et al., 2006) very few differences in acyclic activities, such as passing, receiving, dribbling interceptions and headings, were found in response to change of court dimensions. However, Kelly and Drust (2009) found a high number of tackles and shots with a smaller court. The increasing number of tackles on the smaller SSGs court has been attributed to the previous factors, i.e. the smaller area per player gives the opportunity for more body contact. Even if we could not confirm these significant differences amongst all of the three courts in regards to shots, it is interesting that in handball SSGs, players also execute more shots during a game on a smaller court (Table 3). This can be justified by proximity of goals, which can lead the players to make more frequent attempts to goal (Aguiar et al., 2012).

There was no effect of court dimensions on HR. In other cases, such as studies of rugby (Gabbett et al., 2012) and soccer (Aroso et al., 2004; Da Silva et al., 2011;

Köklü et al., 2011; Rampinini et al., 2007) some differences were observed. These studies highlighted the increase of distance covered and HR values of the players parallel with the increase of court dimensions. Only two studies, to the author's knowledge, found an inverse trend with the HR values that increased with the decrease of the court dimensions (Katis and Kellis, 2009; Tessitore et al., 2006). As with our research, there were two other studies that found no difference with the changes of court dimensions. This was probably due to the age of the subject being low (Jones and Drust, 2007) and to the limited sampling (Kelly and Drust, 2009). Furthermore, we have to consider that HR is only a partial measure of load, and sometimes it may not be sufficiently sensitive to differences in actual metabolic demands, especially in handball SSG (Buchheit et al., 2009a).

During the eight-minute SSGs, the players reached near to maximal HR (>90% of HR_{max}) for 42%±12% of total time. This data confirmed the high intensity of the SSGs drills in comparison with a normal match. Indeed, the HR values of the entire match is 82%±9.3% of HR_{max}, and, during the matches, the players HR are for the 10% of the 1st half and for the 4% of 2nd half above 90% of HR_{max} (Póvoas et al., 2012). In longer bouts of SSGs, (10 or 15 minutes), the players might be forced to reduce the intensity of playing to achieve a more normal match intensity. Obviously a comparison between data showed by our research and handball player's HR values should be made with caution. As previous studies revealed, during team sports players adopt pacing strategies; this can modify the HR activities over a longer period as in an entire match (Aughey, 2009; Duffield et al., 2010; Mugglestone et al., 2013).

Certainly the high HR values found were due to the high amount of "distance covered per minute", high incidence of jumps, change of direction and consequent stops after high intensity actions (typical handball actions). If we consider that exercising >85% HR_{max} might be enough to improve maximal cardiovascular function, and in turn, VO_{2max} and the anaerobic threshold (Helgerud et al., 2001; Impellizzeri et al., 2006), the SSGs used here may be useful for improving the aerobic endurance of the handball players.

The further analysis of effort using the RPE scale showed a greater value for the 32×16m court drill compared with the 24×12m. These differences underlined a general increase of values with the increase of the court dimensions. Similar results were also reported in two studies of SSGs in soccer, i.e. the lower RPE values corresponded to the smaller court (Casamichana and Castellano, 2010; Rampini et al., 2007). The increasing of the RPE with the increasing of space available for each player, without the same trend emphasized by the HR, was also found by a rugby study by Kennett et al. (2012). Probably, the observed dissociation between RPE and HR could be related to greater variability of RPE compared with HR (Hill-Haas et al., 2008). The RPE also have a multifunctional nature, which is mediated not only by physiological but also by psychological factors (Borg et al., 1987; Morgan, 1994). Finally, comparing our results with those of Buchheit et al. (2009a), we found a higher values of RPE on the 32×16 court (the only that was similar to the abovementioned study for single player's pitch space). This difference (8.2 ± 1.0 vs. 6.3 ± 0.5), could be due to the brief rest of 30 seconds inserted in the study of Buchheit, which allowed players to recover. Nevertheless, comparisons between these two studies have to be made carefully, because of the differences in the experimental procedures.

Conclusion

Both findings of this research, regarding the external and internal loads to which the handball players were exposed during the SSGs drills, are certainly helpful for handball coaches and athletic trainers wishing to use specific training methods. The high ratio of cyclic activity per minute and the high HR values recorded make this type of drills extremely useful for aerobic power training. The presence of a large number of jumps makes the SSGs, in particular on the 24×12m court, useful also for training jump ability in fatigue condition. The little space available for the players might limit the expressions of high speed of run, so it is also advisable to use the regular handball court to do the SSGs, with the aim of allowing players to express their maximum speed. Furthermore, because of the great number of defensive activities, the 24×12m court SSGs might be useful in developing the 1 vs. 1 skill of handball players.

Considering the great amount of shooting for goals reported, SSGs with all the three court dimensions are useful in developing the goal making ability of handball players in circumstances of general fatigue.

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Key points

- To cover the specific game demands, more specific training methodologies have been developed in many sport games.
- Specific game exercises may provide a useful conditioning stimulus, together with technical and tactical training components.
- Changing court dimensions during small-sided handball games can be used to manipulate both external and internal loads on the players.
- The high ratio of cyclic activity per minute and the high HR values recorded during SSHGs make this type of drills extremely useful for aerobic power training.

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