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Overview of Motor Skills in Female Elite Rink Hockey Players

Überblick über die Ausprägung motorischer Fähigkeiten bei Elite-Rollhockeyspielerinnen

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Summary

- **Introduction:** Rink hockey is a team sport characterized by intervals of different intensities. Only few studies have been published in the scientific literature to date.
- **Aim:** The intention of this examination was to describe the performance capability of female rink hockey players in order to enhance the understanding of the sport's peculiarities and to improve training scheduling. Investigations of the endurance, strength, functional movements as well as sprint and jump abilities were conducted in 12 female rink hockey players of a national league team.
- **Results:** Endurance values of 2.86±0.51 W/kg and an estimated maximum oxygen uptake of 38.6±6.1 ml*kg-1*min-1 were obtained in the investigation. Isokinetic testing revealed a balanced leg strength (extensors right 2.0, left 1.9 Nm/kg, flexors 1.0 Nm/kg both legs). The average sprint times were slower for those trials with skates than in trials with shoes 5 m, 5-20 m and 20 m (1.40 vs. 1.39 / 2.52 vs. 2.47 / 3.92 vs. 3.86 s). Similar average jump heights were measured for different tasks (counter movement jump 28.3 vs. drop jump 28.0 cm). The average score of the FMS™ amounted to 16.2.
- **Discussion:** The results of the present study reveal improvable endurance, deficiencies in some functional movements and reduced sprint ability in female rink hockey players. The hamstrings to quadriceps torque ratio and the relative torque appear to be similar to other athletes. The mean jump ability of female rink hockey players is similar to adult female college students.

KEY WORDS:
Rink Hockey, Performance, Isokinetic, Estimated Oxygen Uptake

Zusammenfassung

- **Einleitung:** Rollhockey ist ein Mannschaftsport, der durch wechselnde Belastungsintensitäten charakterisiert ist. Bisher liegen nur wenige wissenschaftliche Untersuchungen vor, die sich mit Rollhockey auseinandergesetzt haben.
- **Ziel:** Das Ziel der Untersuchung bestand in der Beschreibung der Leistungsfähigkeit von Rollhockeyspielerinnen, um die sportartspezifischen Besonderheiten zu verstehen und die Trainingsplanung zukünftig zu verbessern. Es wurden Untersuchungen zur Ausdauer, Kraft, funktionellen Beweglichkeit sowie zu Sprint- und Sprungfähigkeiten bei 12 Rollhockeyspielerinnen einer Bundesligamannschaft durchgeführt.
- **Ergebnisse:** Als Resultat der Ausdaueruntersuchung konnten eine Leistung von 2,86±0,51 W/kg und eine daraus abgeleitete durchschnittliche maximale Sauerstoffaufnahme von 38,6±6,1 ml*kg^{-1}*min^{-1} bestimmt werden. Die isokinetische Kraft der Extensoren (rechts 2,0, links 1,9 Nm/kg) und der Flexoren (1,0 Nm/kg links und rechts) waren im Seitenverhältnis ausgeglichen. Die Sprints mit Rollschuhen ergaben langsamere Zeiten im Vergleich zu den Sprints mit Sportschuhen auf 5 m, 5-20 m und 20 m (1,40 vs. 1.39 / 2,52 vs. 2,47 / 3,92 vs. 3,86 s). Bei den unterschiedlichen Sprungmustern wurden gleiche durchschnittliche Sprunghöhen erreicht (Counter Movement Jump 28,3 vs. Drop Jump 28,0 cm). Der mittlere Score beim FMS™ betrug 16,2.
- **Diskussion:** Die Ergebnisse der Studie weisen auf eine ausbaufähige Ausdauer, Einschränkungen bei der funktionellen Bewegungsausführung und eine reduzierte Sprintfähigkeit bei Rollhockeyspielerinnen hin. Das Kraftverhältnis von Flexoren zu Extensoren (HQ) ist ähnlich ausgeprägt wie bei anderen Athletinnen, ebenso wie das relative Drehmoment. Die Sprungfähigkeit von Rollhockeyspielerinnen entspricht der erwachsener College-Studentinnen.

SCHLÜSSELWÖRTER:
Rollhockey, Leistung, isokinetisch, abgeschätzte Sauerstoffaufnahme

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Introduction

Rink hockey for senior female athletes is a team sport with a duration of 40 minutes and a 10-minute halftime break in between. A draw results in an another resting period of three minutes followed by 10 minutes overtime divided in two halftimes, which are interrupted by a break of two minutes, if a winner is needed. Sudden death in the overtime is possible. Is the game still tied, teams have to undergo a shootout. Rink hockey matches consist of intervals of different intensities (25). The game is played on a 20m x 40m court by 5 players (one goalkeeper) each team, with sticks and a rubber ball (14, 30). There is only a small amount of English literature published that deals with rink hockey. However, they include a small number of participants only and address the characteristics of male rink hockey players solely.

Studies about female rink hockey players are still lacking. Female athletes who participate in game sports are similar regarding the physiological and physical preconditions, which are better evolved than in ordinary humans (5). The purpose of this examination was to describe the profile of female rink hockey players for a better understanding of the characteristics of the sport and as part of short-, medium- and long-term training scheduling. It was hypothesized that female rink hockey players possess distinct developed performance abilities comparable to other (team) sport athletes.

Methods

Subjects

As part of the preparation for the season and in the context of the yearly medical check-up we investigated 12 female rink hockey players of a German Bundesliga team (age 16.3±3.9 y, body mass 60.5±14.8 kg, body height 163±8 cm, body mass index 22.7±4.8kg/m^2, body fat 24±5.4%). The training volume amounts almost 3.5 sessions resulting in approximately 4.5 hours a week. Body fat was determined by the measurement of 10 skinfolds (cheek at the level of the tragus, base of the mouth, first quarter inferior of the navel between navel and anterior inferior iliac spine, 10th rib at the level of the anterior axillary line, superior of the anterior inferior iliac spine, superior of the patella, subscapular, triceps brachii muscles between acromion and olecranon, anterior axillary skinfold, inferior line of the popliteal fossa) with a caliper (16).

Informed consent was obtained from all individual participants (signed by the legal guardian in the case of under legal age) included in the study after briefing. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The authors disclose potential conflicts of interest to the subjects. The participants should have had a high-carbohydrate intake 2 days prior to the investigation as well as no or little coffee or tea, no nicotine and no alcohol on the day of the investigation. Furthermore, they should avoid very extensive or intensive training 2 days prior to the investigation, higher physical or psychological strains one day before and also low physical strains on the day of the investigation.

Measurements

Within the scope of this performance inquiry and evaluation study, every athlete had to undergo laboratory and field tests on 2 different days. The aim was to collect performance data that are utilizable for a classification and a comparison to other collectives. To assess the functional capabilities, the athletes performed the Functional Movement ScreenTM (FMS™), which consists of 7 main movements, where 21 being the maximum value to reach. The estimation of strength was conducted with an isokinetic torque measurement of the knee extensor and the knee flexor muscles. 11 athletes underwent a test at 60°/s speed within a single leg design with 5 repetitions/leg in seated position on an isokinetic extremity system (HUMAC® NORM™; Computer Sports Medicine, Inc.). The motion ranged from the full extension to a self-chosen flexion with a minimum angle of 90°. In the process, the softest damping was chosen. The axis of the device was visually aligned with the axis of the knee. The thigh of the active leg was fixed with a strap above the knee. The lever arm was attached distally of the shank above the malleolus. The contra lateral leg was placed behind a leg stop. The athletes were asked to grab the sidebars of the seat. The range of motion was determined by the athlete whereby a maximal active extension was requested. The measurement was conducted with a static ascertained gravity correction. The preparation prior to the testing consisted of an individual self-selected number of repetitions without load (only lever arm) and 4 submaximal repetitions at the test speed. The athletes were instructed to conduct the test as intense and fast as possible. Endurance was examined on a speed independent bicycle ergometer (Excalibur sport, Lode B.V.) within an incremental protocol starting with 50W, increment durations of 3 min, increments of 25 W and 60-90 rpm. The maximum aerobic performance capability was assessed by use of an equation to estimate the VO_2 based on the power output reached on the cycle. The equation consists of a resting component, a horizontal component and a vertical component/resistance component (3.5+3.5 + (1.8 * work rate in k*m*min^{-1})/body mass in kg) (2). Under resting conditions, after every increment and 4 times until 10 min following the load, lactate samples from the ear were taken and blood pressure was measured. The whole time, ECG (Schiller CS-200, SCHILLER Medizintechnik Gmbh) was monitored and recorded. The first part of the field tests with 9 athletes contained a 20 m dash with a double light barrier system (Kit Racetime2 Light Radio, Microgate Srl) to assess the sprint ability. The athletes started arbitrary (no reaction necessary), 2 times with athletic shoes and 2 times with skates in an upright step position immediately behind the first light barrier. The best time at 5 and at 20 m was selected for the evaluation. The second part of the field test consisted of 2 counter movement jumps with arm swing and 2 drop jumps without a special arm movement/position (box of 30 cm height). They were measured via flight time with a light barrier system (Optojump next, Microgate Srl) to assess the functional power. The highest value was selected for the evaluation. For the sprint tests and the jumps, 9 athletes could be included.

Statistics

The data were worked off descriptive (mean, standard deviation, minimum and maximum). The analysis of the distribution was conducted with the Shapiro-Wilk test. The Wilcoxon test was used to compare the central tendency between the sprint ability with skates and with shoes for not normally distributed values. To analyze the relation between sprints with shoes and with skates, the Spearman correlation was calculated for values not normally distributed. The level of significance was determined at $p<0.05$. The calculations are based on a statistic program (IBM® SPSS® Statistics 22.0.0.0; IBM Corp.©).

Results

Considering the maximum heart rate (188±12 beats*min^{-1}) in comparison with the target heart rate of 200-age (102.5±5% of target) and the peak blood lactate concentration (9.88±2.19 mmol*L^{-1}), an exhaustion in the endurance test was reached. The mean aerobic capability was estimated with 38.6±6.1 ml*kg^{-1}*min^{-1} (2.27±0.31 L*min^{-1}) via the reached power of 166±21 W (2.86±0.51 W/kg). The average isokinetic strength was balanced between the legs and about twice as high (Hamstrings-Quadriceps-Ratio 0.52 ± 0.08 right and 0.53±0.08 left) for the extensors (117.7±32.2 Nm or 2.0±0.5 Nm/kg right and 111.5±25.4 Nm or 1.9±0.3 Nm/kg left) in comparison to the flexors (59.8±11.5 Nm or 1.0±0.2 Nm/kg and 57.8±8.0 Nm or 1.0±0.2 Nm/kg left). The average sprint times were slower for those trials with ›

Table 1

Performance data of female rink hockey players (†calculated maximum oxygen uptake, #target heart rate 200 minus age, SD=standard deviation, *not normally distributed sprint time p<0.05).

ENDURANCE (N=12)	MEAN±SD	MINIMUM	MAXIMUM
Maximum power [W]	166 ± 21	129	198
Maximum power [W/kg]	2.9 ± 0.5	2.1	3.5
Maximum oxygen uptake [L·min^{-1}]†	2.27 ± 0.31	1.69	2.64
Maximum oxygen uptake [ml·kg^{-1}·min-1]†	38.6 ± 6.1	30.0	46.0
Peak blood lactate concentration [mmol·L^{-1}]	9.88 ± 2.19	7.40	14.50
Maximum heart rate [beats·min^{-1}]	188 ± 12	170	208
Heart rate percent of target [%]	102.5 ± 5.0	96.7	111.2
STRENGTH (N=11)			
Knee extension max right [Nm/kg]	2.0 ± 0.5	0.9	2.6
Knee extension max left [Nm/kg]	1.9 ± 0.3	1.3	2.2
Knee flexion max right [Nm/kg]	1.0 ± 0.2	0.6	1.3
Knee flexion max left [Nm/kg]	1.0 ± 0.2	0.7	1.4
Knee extension max right [Nm]	117.7 ± 32.2	73.0	191.0
Knee extension max left [Nm]	111.5 ± 25.4	80.0	168.0
Knee flexion max right [Nm]	59.8 ± 11.5	39.0	73.0
Knee flexion max left [Nm]	57.8 ± 8.0	41.0	69.0
Hamstring-Quadriceps-Ratio right	0.52 ± 0.08	0.38	0.62
Hamstring-Quadriceps-Ratio left	0.53 ± 0.08	0.41	0.66
SPEED (N=9)			
5 m [s]	1.39 ± 0.12	1.23	1.58
5 m [s] roller skates*	1.40 ± 0.10	1.31	1.65
5-20 m [s]*	2.47 ± 0.17	2.33	2.77
5-20 m [s] roller skates	2.52 ± 0.15	2.33	2.78
20 m [s]*	3.86 ± 0.27	3.62	4.36
20 m [s] roller skates*	3.92 ± 0.25	3.70	4.39
POWER (N=9)			
Counter movement jump height [cm]	28.3 ± 3.7	22.5	32.3
Drop jump height [cm]	28.0 ± 4.3	19.6	33.7
Drop jump time of contact [sec]	0.34 ± 0.06	0.26	0.44
FUNCTIONAL MOVEMENT (N=12)			
Functional Movement Screen (™) score	16.2 ± 1.6	13	18

skates. Calculations between values of the different trials with skates and those with shoes showed a significant difference for the 20 m distance times, but not for the others. Correlations were found for 5 to 20 m and 20 m. The power representing different jumping tasks showed similar average heights (counter movement jump 28.3±3.7 cm vs. drop jump 28.0±4.3 cm, contact time 0.34±0.06 sec). The FMS™ resulted in an average score of 16.2. Details of the results are listed in summarized in table 1, calculations of the central tendency and correlations in table 2.

Discussion

This is the first description of the performance profile of female rink hockey players known by the authors. Due to the lack of data, a comparison and classification seems to be difficult. Disparities and wide ranges in anthropometric data and testing results can be explained by the age differ-ences.

Functional Movement

At the FMST™, maximum values were reached at "Shoulder Mobility" and "Inline Lunge" (MW 2.83±SD 0.39). The minimum values were obtained at "Rotatory Stability" (1.92±0.29). The other values of the remaining units ranged from 2.00±0.43 to 2.25±0.45. Save for "Shoulder Mobility" and "Inline Lunge" (respectively, with 2 exceptions), there is in all tested units potential for improvements, e.g. in core strength, upper body flexibility and hip stability. Limitations of the core conceivably enhance the hazard to suffer injuries in the lower extremities (29). For example, reduced core strength in soccer players can embody a risk factor for a lesion of the anterior cruciate ligament (ACL) (1).

Endurance

Within the endurance test, the athletes on average reached an exhaustion which was assessed on the basis of the maximum heart frequency and the highest lactate value. Using the maximum oxygen uptake (VO_2max in ml*kg^{-1}*min^{-1}) for a

classification of the endurance, the values reveal a wide ranged performance ability. Both estimated reference values for adults and adolescents were consulted (7, 24). In comparison with normative estimated VO_2max values for U.S. adolescents examined on a treadmill, the percentiles for adolescent rink hockey players range from 10th to 75th percentile for theirs estimated values. The data suggest that the younger athletes (12-13 years) had the best endurance and gained, consistent with the literature (8), a higher relative maximum oxygen uptake. The endurance of female adult rink hockey players can be assessed as moderate in relation to adults aged between 20-29 years. Though, estimated or measured values of those female rink hockey players who participated in this study might be higher on a treadmill. When classifying the VO_2max values on a treadmill for male athletes, Hoppe et al. (14) and Coelho-E-Silva et al. (4) (relative values calculated by the authors) revealed a highly trained aerobic endurance with a big margin to the lower cut off value for the adults and a high percentile classification for the adolescents. This corresponds to pronounced endurance ability. Female athletes who participate in game sports have similar physiological and physical preconditions (5). Thus, a comparison with other team sports might be profitable in order to classify the endurance. Accordingly, a well evolved aerobic endurance is convenient for high level handball (19). The aforementioned investigation of Davis and Brewer (5) of female soccer players yielded values for VO_2max between 47.1 and 57.6 $ml*kg^{-1}*min^{-1}$.

Strength

The literature suggests that at the age of 14 years the isokinetic strength of the knee extensors and flexors of girls achieve a maximum amount which persists (6). Therefore, an intra-group comparison with the younger athletes concerning strength appears to be difficult. Coelho-e-Silva et al. (4) used a partially comparable test protocol to test male rink hockey players but without giving any information concerning gravity correction. Lower values were attained using corrected and not corrected values for the comparison. Under the premise that the data were gravity corrected, the difference amounts 26% to local and 34% to international male rink hockey players for the extensors and 32% respectively 38% for the flexors (without correction, the difference to the extensor is slightly higher and to the flexors slightly lower). The comparison to 32 female 15 to 18 year-olds, in recreational or interscholastic sports active students reveals similar or slightly higher torque extensor respectively flexor values for the tested athletes in the present study (dominant limb extensors corrected 2.0 vs. 1.79 Nm/kg; dominant limb flexors corrected 1.0 vs. 0.99 Nm/kg). This depends on whether gravity corrected or no corrected values are used for the evaluation, because no information about gravity was given (13). A difference in strength between the extremities of less than 10% appears to be normal (20). Out of 11 athletes, 6 for the extensors and 3 for the flexors showed a conspicuous difference, whereby respectively 2 for each muscle group revealed a difference greater 20%. The greatest difference observed in one of the goalkeepers is maybe attributable to the unilateral kneeing positioning in the game. It is suggested that pronounced strength in hamstrings related to the quadriceps is protective for the knees (12). The hamstrings to quadriceps torque ratio amounts 0.52 (±0.08 right and ±0.07 left) for both legs in the present study and is comparable with values in the literature. An investigation of 55 female athletes from different sports (soccer, softball, volleyball, basketball) revealed gravity corrected mean values for the hamstrings-quadriceps-ratios of 50.1 on the right and 48.8 on the left side. Lowest values were given for softball players (46.6 left and right); highest for basketball players (55.0 right) (23). A low strength of the hamstrings in relation to the quadriceps appears to be a risk factor for an ACL injury in soccer players (1). If the relation between hamstrings and quadriceps approaches a balance (hamstrings-quadriceps-ratio tend to 1.0) a lower risk of hamstring injury (21) and a reduction of the presumption of a subluxation of the tibia in ACL patients might exist (17). Nevertheless, it is obvious that the measured maximum force (in the lab) can't be evolved within explosive tasks. Furthermore, ratios of concentric and eccentric strength respectively ratios at certain angles embody other possibilities to evaluate the joint function (15).

Table 2

Comparison and correlation of sprint abilities (shoes vs. skates) of female rink hockey players (*significant difference p<0.05, **high significant difference p<0.01, n=9).

DISTANCE	WILCOXON ASYMPTOTIC SIGNIFICANCE	SPEARMAN-RHO CORRELATION (SIGNIFICANCE)
5 m	0.484	0.460 (0.213)
5-20 m	0.068	0.854 (0.003)**
20 m	0.028*	0.736 (0.024)*

Sprint Capacities

Strength and power may be linked with sprint ability (19). The comparison between skates and shoes only resulted in statistical significant difference between the 20 m dashes, but not for the 5 m and the 5-20 m running times. To question is the meaning of the differences. In only 3 athletes there were differences greater 1/10 s (lower 3/10) in several considerations of all distance sections (partly in sections which not differ significantly in the group comparison. Furthermore the significance is absent by using the Bonferroni correction for multiple testing (in the case of using 6 tests p<0.0083 instead of 0.05). The absence of a correlation of sprint times between shoes and skates on the first 5 m probably is explainable with a lack of internal consistency perhaps caused by differences in the developmental stage of the starting technique with skates. The correlation between 5-20 m times is significant. Between 20 m times the conspicuous correlation is absent when the Bonferroni correction is applied. To demonstrate the meaning of sprint abilities, a comparison with other interval team sports is useful as well. Female soccer players show better sprint results than ordinary people (5). Also for female handball players sprint ability is a significant requirement (9). Within an investigation with 9 female team sport players on recreational level aged eighteen years or older (22.7±5.1) better 5 m, 20 m and calculated 5-20 m times (1.156±0.043, 3.453±0.120 and 2.297 s calculated) were observed (18). A survey with 194 female soccer players, aged between 15 and 35 years and divided in categories respectively their level, position and age, observed the sprint ability (11). Both, national team players and junior elite players spurted faster on 20 m than the rink hockey players of the present study (3.05 respectively 3.12 s calculated). Also, the divided age groups <18 years to >25 years showed a better sprint ability with results between 3.11 and 3.12 s An evaluation with 140 high-level soccer players (23.9±2.8 years) within the scope of a try-out revealed sprint values of 1.19; 3.40 and 2.21 s for the distances 5 m; 20 m and 5 to 20 m (27). The mean sprint times of the female rink hockey players are located below the tenth percentiles of ›

the latter study. Hence, the sprint ability is classifiable as very low. The comparison of the present results with values of male rink hockey players with skates for the same distances (5 m, 5-20 m, 20 m) reveal 19%, 15% and 16% slower sprint times for the females (14).

Jump Capacities

Regarding jump examinations, different conductions are presented in the literature. The counter movement jump might be conducted with or without (hands akimbo) arm swing. The most prominent difference between drop jumps is the starting height. The results of the jump tests reveal the same mean jump height with the drop jump and the counter movement jump (28.0±4.3 and 28.3±4.3 cm). A study with 25 young adult female college students resulted in 27 cm jump height by use of a counter movement jump with arm swing (28). With the same execution a gender mixed collective of 127 female and 197 male students aged between 10 and 18 years (average 12.8 years) achieved heights between 22.8±5.5 (sedentary) and 27.9±6.8 cm (active). Relating to a couple of studies citied in this study, an increase of the jump height of 10-20% by using an arm swing while the conduction of the countermovement jump in comparison without arm swing was stated (22). Considering the age, three athletes of the present study are directly comparable with values of a study by Taylor et al. (26), which included 1845 children aged 10-15 years. Two of them jumped significantly higher (31.5 vs. 26.9±4.9 cm and 32 vs. 27.1±5.0 cm) and one athlete reached a considerably lower height (22.5 vs. 28.7±6.7 cm) than the average results. The high body fat value in the latter athlete (31.9%) might be also an explanation for the jump performance (22.7 cm) of another athlete of the present study (30.8% body fat) aged seventeen years. Recently raised data of male rink hockey players showed a significantly higher average of 45.9 centimeter jump height (14). But values of male volleyball players are still conspicuously higher, partly with jumps above 60 cm (31). The drop jump in the present trial was performed from a 30 cm box. An investigation of sixteen 15.5±1.5 year old high school level volleyball girls revealed an average jump height of 38.2 cm (10). Another investigation with 29 approximately 20-year-old female volleyball players divided in three groups by their division level resulted in 32.6 (Division III), 32.1 (Division II) respectively 36.0 cm (Division I) drop jump height by use of jump and reach (one hand) with a Vertec device (3). In this context, the contact time in the present study is slightly lower (0.34 vs. 0.42-0.44 s). This suggests a consideration of both values (height and contact time) in the context. The average drop jump height in the present study is lower, but for some athletes values were close to respectively one athlete surpassed the average of the aforementioned results. The large range supports the performance heterogeneity of the present collective.

Practical Applications

Coaches and athletes are encouraged to enhance especially endurance and sprint performance. To question is the low cut-off age to become admitted in senior teams and therefore the wide distribution of the age. Closely connected with this issue is the small number of female rink hockey players which represents a limitation in this study. A possibility to explain the improvable performance might be the training exposure. The athletes in the current study train almost 3.5 sessions a week resulting in approximately 4.5 hours. To question is the intensity of the training while undergoing this training volume. Furthermore to consider is the minor number of English written scientific literature on the topic. The lack of information to gravity correction while strength testing aggravates the classification of the data.

Conclusions

The current study presents for the first time an overview of physical fitness in female rink hockey players on Bundesliga level. The results of the present study reveal inhomogeneous performances and suggest an improvable endurance, deficiencies in some functional movements, a reduced sprint ability and conspicuous differences in leg strength in some cases. The hamstrings to quadriceps torque ratio of the rink hockey players appears to be similar to athletes of different sports, nevertheless a higher ratio might decrease injury risks. The relative torque appears to be at least not lower than depicted in the literature. The mean jump ability of female rink hockey players is similar to adult female college students.

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Conflict of Interest

The authors have no conflict of interest.

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