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The Relationship between Clinical Tests, Ultrasound Findings and Selected Field-Based Wheelchair Skills Tests in a Cohort of Quadriplegic Wheelchair Rugby Athletes: A Pilot Study

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Abstract: Manual wheelchair use may determine shoulder joint overload and rotator cuff injury. Chronic shoulder pathologies can also influence the propulsion ability of wheelchair athletes with spinal cord injury (SCI) during sport activities. However, the relationship between shoulder pathology and wheelchair performances has never been explored. Therefore, the study aimed to investigate the correlation between shoulder pathologic findings with clinical tests and ultrasonography evaluation and the results of wheelchair performance tests. Nineteen quadriplegic wheelchair rugby players were evaluated to investigate the association between clinical and ultrasound shoulder pathologic findings and their correlation with the performance of field-based selected wheelchair skills tests (WSTs). The outcome measures were the International Wheelchair Rugby Classification Score, dominant and non-dominant Physical Examination Shoulder Score, and dominant and non-dominant Ultrasound Shoulder Pathology Rating Scale (USPRS). The WST was measured at the beginning and at one-year follow-up. A statistically significant correlation was found between the time since SCI and dominant USPRS ($p < 0.005$). The non-dominant USPRS was strongly related to WST at the beginning ($p < 0.005$) and the end of the study ($p < 0.05$). Data suggest that the severity of the non-dominant shoulder pathology detected on the ultrasound is related to lower performance on the WST. Chronic manual wheelchair use could be responsible for dominant SCI shoulder joint and rotator cuff muscle damage, while non-dominant USPRS could be related to performance on the WST.

Keywords: spinal cord injury; wheelchair rugby; wheelchair skills test; shoulder ultrasound

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1. Introduction

Wheelchair rugby is a popular Paralympic team discipline available to individuals with different disabilities that affect arms and legs; most athletes present a cervical spinal cord injury (SCI) with full or partial paralysis [1].

Wheelchair rugby is considered a sport with high risk of injury, and athletes are more prone to injuries of the upper extremities [2–4]: manual wheelchair use may determine shoulder joint overload, and repetitive microtraumas can cause rotator cuff tendinopathy and muscle tears [5,6]. The presence of chronic shoulder pathologies often causes symptoms such as pain, stiffness, weakness, and joint instability, hence it could also impact the wheelchair athletes' propulsion ability during sport activities [2,7,8].

Shoulder ultrasound represents an extremely sensitive imaging tool to investigate the presence of shoulder joint and rotator cuff disease, even in manual wheelchair users. It represents a non-invasive, cost-effective, rapid, easily accessible real-time exam, and can be employed on the sport field during training and competitions. However, the inconvenience is that it does not provide any direct information about the wheelchair performance of athletes [9].

In order to assess athletic performance, many wheelchair skills tests (WSTs) have been employed [10–12]. Among them, team coaches seem to prefer the field-based test for their ease of execution and reliability in mimicking game situations [13]. During these tests, participants must perform motor skills required in wheelchair sport activities such as sprints, changes of direction, obstacle avoidance, braking, etc. Together with information about the athlete's performance, these tests can provide several biomechanical parameters that could be affected during wheelchair propelling (e.g., the change in human body center of gravity position, which is connected to the different rolling resistance between initial and final stages of the propulsion phase, and between front and rear wheels) [14]. The analysis of these parameters provides important information about the musculature involved during wheelchair propulsion, because acceleration, braking, turning, and ball handling are hardly dependent on trunk stability and upper extremity strength. These characteristics are often compromised in athletes with SCI, who compensate the impairment with alternative postural strategies and the activation of compensatory muscles [15–17].

The results of these tests give some quantifiable information related to the propulsion ability of the athlete [10–13,18], but they do not provide any clue about the factors that affect wheelchair performance.

Many studies have shown the negative influence of manual wheelchair use on the shoulder joint and rotator cuff muscles [5,19], but, to the best of our knowledge, the relationship between shoulder pathology and wheelchair performance has never been explored.

Therefore, the purpose of this study was to conduct a clinical and ultrasonographic evaluation of dominant and non-dominant shoulder conditions of a cohort of wheelchair rugby players, and their correlation with the results of two wheelchair performance tests evaluating the propulsion speed and the wheelchair mobility skill. The hypothesis was that the worse the results of the WST, the more the shoulder damage would have been.

2. Materials and Methods

This was an observational prospective study on a cohort of wheelchair rugby athletes. Nineteen quadriplegic male members of the Italian National Wheelchair Rugby Team with a history of traumatic spinal cord injury (SCI) were enrolled.

The athletes were included in the study if they had a history of at least five years of SCI that limited mobility of both arms, and if they used a manual wheelchair as the primary means of mobility during daily life and a defensive wheelchair rugby chair during sport activities. The exclusion criterion was a history of shoulder joint traumatic injuries such as fractures or traumatic rotator cuff muscles tears.

This study followed all the recommendations for research in human beings and all participants signed an informed consent form before the assessments, in accordance with procedures of the Institutional Review Board.

Age, level and age of SCI, number of daily transfers, body mass index (BMI), and defensive wheelchair rugby chair weight were measured. Moreover, the International Wheelchair Rugby Federation Classification (IWRFC) score for each participant was registered. IWRFC classifies players in seven groups depending on their level of disability, ranging from 0.5 (most impaired) to 3.5 (least impaired) [20].

Each athlete underwent a neurological physical examination to determine the motor level, the sensory level, and the completeness of SCI, and the American Spinal Injury Association Impairment Scale (AIS) score was determined accordingly. AIS classification identifies key muscles and sensory points corresponding to different myotomes and dermatomes for each side of the body. The motor score is based on the strength of 10 pairs of key muscles in the upper and lower limbs; the sensory score is based on pin-prick and light touch scores in each of the key sensory dermatomes [21].

Shoulder examination was also performed, and the Physical Examination Shoulder Score (PESS) of both the dominant and non-dominant shoulder was calculated. PESS is a shoulder evaluation scale that was firstly described and validated by Brose et al. [22]. It consists of 11 physical examination maneuvers for rotator cuff disease and shoulder pain that are graded 0 (no pain), 1 (equivocal for pain), or 2 (pain present). PESS maneuvers consist of palpation over the bicipital groove/bicep tendon; palpation over the greater tuberosity/supraspinatus tendon; palpation over the acromioclavicular joint; Neer sign; Hawkins–Kennedy sign; shoulder range of motion; Jobe's test; resisted external rotation; resisted internal rotation; and O'Brien test for the labrum, O'Brien test for the acromioclavicular joint. PESS can range from 0 (best score) to 22 (worst score).

A B-mode sonographic evaluation of both shoulders was performed by a radiologist with a SonoSite M-Turbo® machine (Fujifilm Sonosite Europe, Amsterdam, 1114 AB, Netherlands) and a 6–13 MHz linear transducer. The examiner (a certified medical sonographer) was blind to the results of the physical examination. Subjects were evaluated in a sitting position and the examination was conducted according to the Musculoskeletal Ultrasound Technical Guidelines of the European Society of Musculoskeletal Radiology [23].

The Ultrasound Shoulder Pathology Rating Scale (USPRS), developed and validated by Brose et al. [22], was used to quantify the severity of shoulder pathology of each athlete. This scale considers 5 pathologic findings: greater tuberosity cortical surface irregularity; supraspinatus tendinopathy; bicipital tendinopathy; supraspinatus impingement; and subscapularis/biceps/coracoid impingement. The USPRS score is determined by the sum of the 5 scores, with a maximum total score of 20 (worst score), and the shoulder pathology depends on the presence and the severity of these findings. The USPRS results of the dominant and non-dominant shoulder were recorded.

The WSTs were conducted in the sports hall at the beginning (within one day after the shoulder examination) and the end of the study (after one year). During the year of observation, the athletes did not have to change their habitual physical activity and gathered each month for a two-day training session.

The WST consisted of a 20 m sprint and a 30 m figure-of-eight sprint on smooth terrain, and has been described in many studies. The 20 m sprint evaluates the displacement speed in a straight direction, and the 30 m figure-of-eight sprint measures wheelchair performance over obstacles and in tight spaces along a figure-of-eight-shaped path (Figures 1 and 2) [10,11,24,25]. Before each testing session, the participants were encouraged to perform the tests at maximum intensity, and shoulder pain was measured using the Visual Analogue Scale (VAS). A standardized warm-up of 15 min was undertaken. Each athlete performed both tests three times using his sport wheelchair, with a 10 min recovery before each test. The rater was positioned at the finish line to record the test performance time using a manual chronometer. Only the best sprint time at the beginning and the end of the study were considered as outcome variables for statistical analysis.

Figure 1. Representation of the 20 m figure sprint. The figure shows the distance in meters (m) separating the six obstacles (cones, red circles).

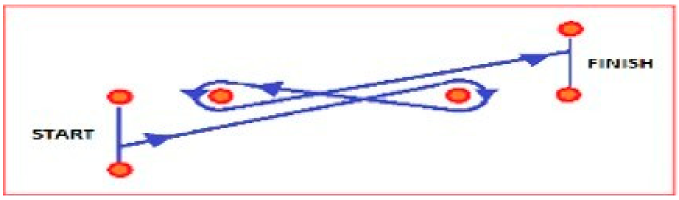

Figure 2. Representation of the 30 m figure-of-eight sprint circuit's trajectory from the start to the finish line.

3. Statistical Analysis

All data analysis was performed using SAS Enterprise Guide 7.1 software. The correlation between the different variables was calculated using the non-parametric Spearman's rank correlation test. Comparison between the results of the dominant and non-dominant PESS, of the dominant and non-dominant USPRS score, and the WST results at baseline and after one year were investigated using the Mann–Whitney U test for nonparametric variables. For all statistical analyses, a significance level of $p < 0.05$ was considered.

4. Results

Nineteen male athletes were enrolled in the study. Three athletes were absent on the days in which the WSTs were repeated, after one year, and were excluded from the statistical analysis. None of the participants reported acute musculoskeletal injuries during the study period.

Sixteen subjects were finally included (mean age ± SD: 33 ± 7 years old; age of SCI ± SD: 17.3 ± 7.1 years; time of disability ± SD: 16 ± 7 years; mean BMI ± SD: 22.2 ± 3.8 kg/m; number of daily transfers ± SD, 13.3 ± 2.5) (Table 1). All athletes were right-handed except for two. SCI level ranged from C5 to C8; the most common level of injury was C6 (five participants). Eight patients had complete SCI (AIS A), while eight patients had incomplete SCI (seven AIS B, one AIS C). The IWRFC score was: four athletes, 0.5 points; six athletes, 1.0 point; and six athletes, 1.5 points. All participants used a defensive wheelchair rugby chair whose weight was 16.1 ± 2.3 kg.

Table 1. Subject characteristics. BMI: body mass index. AIS: American Spinal Injury Association Impairment Scale. IWRFC: International Wheelchair Rugby Federation Classification.

Participant	Age	BMI	AIS Score	Years of Disability	IWRFC
1	36	18	AC4	17	1
2	33	19.7	AC7	17	1
3	29	24	BC7	27	1.5
4	43	21.5	AC4	27	1
5	29	23.3	AC6	10	0.5
6	42	20.7	BC7	14	1.5
7	27	18	AC6	7	1
8	37	24.4	BC7	12	1.5
9	30	17.3	BC5	19	0.5
10	25	19.4	CC6	7	1
11	33	19.6	AC5	15	1
12	27	25.9	BC8	8	1.5
13	42	23.7	AC8	23	0.5
14	47	27.1	BC6	7	1.5
15	40	31.6	BC6	20	1.5
16	23	21.1	AC8	23	0.5

Eleven athletes reported shoulder pain during daily activities and only three complained of slight pain before the WST: two athletes for both shoulders and one only for the dominant shoulder; mean VAS score was 1.8 ± 0.4 SD. None of the participants had taken painkillers in the days before the WST.

Bicipital tenderness was found in 42.3% of the athletes, greater tuberosity/supraspinatus tenderness in 15.3%, acromioclavicular joint pain in 7.7%, the Hawkins–Kennedy impingement sign was positive in 3.8% of the subjects, the presence of a painful arc in 7.7%, the Jobe's test in 3.8%, the O'Brien test for the labrum in 11.5%m and the O'Brien test for the acromioclavicular joint in 7.7%. The other physical pathologic signs were absent.

Mean (±SD) PESS was 2.5 (±2.8) for the dominant shoulder, and 1.3 (±1.6) for the non-dominant shoulder. The dominant/non-dominant PESS difference was not statistically significant with a Mann–Whitney U test ($p = 0.712$).

The shoulder ultrasound examination results are shown in Figure 3.

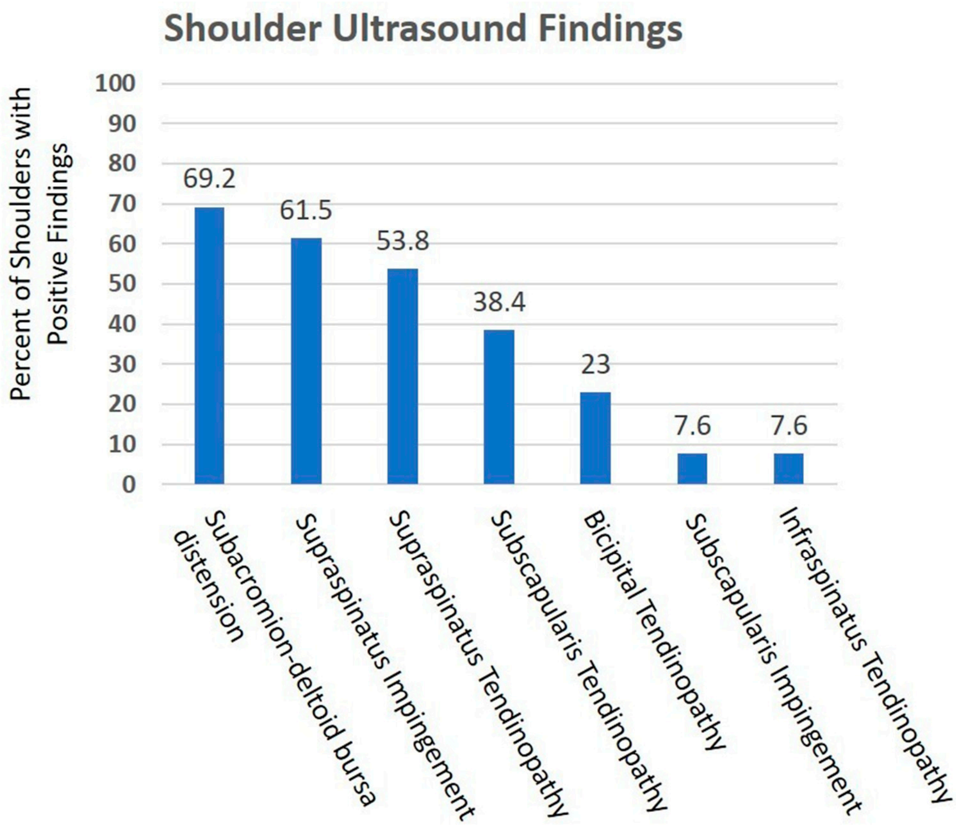

Figure 3. Shoulder ultrasound findings.

Mean (±SD) USPRS score was 2.3 (±3.1) for the dominant shoulder, and 2.1 (±2.1) for the non-dominant shoulder. The dominant/non-dominant USPRS score difference was not statistically significant ($p = 0.712$).

The mean 20 m sprint test time was 7.94 s (range: 6.74–10.72 s) at baseline and 7.92 (6.53–10.33 s) after one year, and there was not a statistically significant difference between these results with a Mann–Whitney U test ($p = 0.74$). The correlation at Spearman's rank correlation test was significant ($\rho = 0.89$ $p = 0.0002$).

The mean 30 m figure-of-eight sprint time was 11.7 s (range: 10.65–16.51 s) at baseline and 10.97 (9.38–13.83 s) after one year. The Mann–Whitney U test result was not significant ($p = 0.19$); the Spearman's test results were significant ($\rho = 0.709$; $p = 0.014$).

The correlations between age, BMI, PESS, USPRS and WST are shown in Tables 2–4.

Table 2. Spearman's correlation coefficients and statistical relationships between age, body mass index, years with spinal cord injury, Physical Examination Shoulder Score of the dominant and non-dominant shoulder, Ultrasound Shoulder Pathology Rating Scale of the dominant and non-dominant shoulder and wheelchair skill tests. Abbreviations: D, dominant; ND, non-dominant; PESS, Physical Examination Shoulder Score; SCI, spinal cord injury; USPRS, Ultrasound Shoulder Pathology Rating Scale; NA, not applicable; ρ = Spearman's rho, * $p < 0.05$.

Spearman's Correlation Coefficients and Statistical Relationships								
	PESS D	PESS ND	USPRS D	USPRS ND	20 m Sprint Time T0	20 m Sprint Time T1	Figure-of-Eight Sprint Time T0	Figure-of-Eight Sprint Time T1
Age	ρ = 0.357 p = 0.281	ρ = 0.055 p = 0.871	ρ = 0.376 p = 0.253	ρ = 0.051 p = 0.879	ρ = 0.154 p = 0.649	ρ = 0.073 p = 0.801	ρ = 0.073 p = 0.883	ρ = 0.095 p = 0.779
Body Mass Index	ρ = 0.014 p = 0.967	ρ = 0.110 p = 0.747	ρ = 0.532 p = 0.091	ρ = 0.032 p = 0.923	ρ = −0.227 p = 0.501	ρ = 0.310 p = 0.280	ρ = 0.418 p = 0.200	ρ = 0.181 p = 0.592
Years with SCI	ρ = 0.027 p = 0.708	ρ = 0.060 p = 0.860	ρ = 0.788 p = 0.003 *	ρ = 0.455 p = 0.159	ρ = 0.027 p = 0.935	ρ = 0.242 p = 0.403	ρ = 0.211 p = 0.532	ρ = 0.082 p = 0.808

Table 3. Spearman's correlation coefficients and statistical relationships between Physical Examination Shoulder Score of the dominant and non-dominant shoulder and Ultrasound Shoulder Pathology Rating Scale of the dominant and non-dominant shoulder and wheelchair skill tests. Abbreviations: D, dominant; ND, non-dominant; PESS, Physical Examination Shoulder Score; SCI, spinal cord injury; USPRS, Ultrasound Shoulder Pathology Rating Scale; NA, not applicable; ρ = Spearman's rho.

Spearman's Correlation Coefficients and Statistical Relationships						
	USPRS D	USPRS ND	20 m Sprint Time T0	20 m Sprint Time T1	Figure-of-Eight Sprint Time T0	Figure-of-Eight Sprint Time T1
PESS D	ρ = −0.323 p = 0.280	ρ = 0.321 p = 0.284	ρ = 0.106 p = 0.769	ρ = 0.085 p = 0.782	ρ = 0.112 p = 0.756	ρ = 0.081 p = 0.822
PESS ND	NA	ρ = 0.534 p = 0.060	ρ = 0.203 p = 0.572	ρ = 0.069 p = 0.821	ρ = 0.160 p = 0.657	ρ = 0.111 p = 0.759

Table 4. Spearman's correlation coefficients and statistical relationships between Ultrasound Shoulder Pathology Rating Scale of the dominant and non-dominant shoulder and Physical Examination Shoulder Score of the dominant and non-dominant shoulder, and wheelchair skill tests. Abbreviations: D, dominant; ND, non-dominant; PESS, Physical Examination Shoulder Score; SCI, spinal cord injury; USPRS, Ultrasound Shoulder Pathology Rating Scale; NA, not applicable; ρ = Spearman's rho, * $p < 0.05$.

Spearman Correlation Coefficients and Statistical Relationships						
	PESS D	PESS ND	20 m Sprint Time T0	20 m Sprint Time T1	Figure-of-Eight Sprint Time T0	Figure-of-Eight Sprint Time T1
USPRS D	ρ = 0.376 p = 0.253	NA	ρ = 0.232 p = 0.518	ρ = 0.201 p = 0.509	ρ = 0.069 p = 0.849	ρ = 0.294 p = 0.408
USPRS ND	NA	ρ = 0.534 p = 0.060	ρ = 0.833 p = 0.002 *	ρ = 0.659 p = 0.014 *	ρ = 0.635 p = 0.048 *	ρ = 0.796 p = 0.005 *

5. Discussion

Findings of our study showed that a possible correlation between the increasing amount of shoulder pathology on ultrasound examination and the worse performance of WST exists only for the non-dominant shoulder ($p < 0.05$ in both sessions), as observed from the comparison between the USPRS of the non-dominant shoulder (USPRS ND in Table 4) and both the 20 m sprint and figure-of-eight sprint tests.

These data could be explained by the fact that manual wheelchair propulsion is an asymmetrical act, during which the magnitude of contribution of rotator cuff muscles while propelling is different from side to side; this difference may become more pronounced during challenging conditions [23,26]. A previous study investigating asymmetries in bilateral scapular kinematics in a cohort of wheelchair athletes during activities of daily life (ADL) found limited associations to shoulder pain [27]. However, as the authors claimed, the ADL wheelchair propulsion can be considered a "low risk" activity in developing shoulder pain, probably due to the lower shoulder elevation required during ADL and the lower stresses to which rotator cuff muscles and tendons are subjected.

In our study, the consequences of asymmetrical shoulder joint overload during challenging conditions are documented by the clinical (PESS) and ultrasonographic (USPRS) scores. The non-dominant shoulder had better scores than the dominant one, even if the differences were not statistically significant; this could be due to the small sample size. We speculate that the statistical correlation between non-dominant USPRS scores and WST performances could be consequent to the fact that during ADL, the non-dominant shoulder is probably less used by manual wheelchair users and therefore less damaged. Consequently, it could make a more significant contribution than the other shoulder during speed tasks.

To the best of our knowledge, this is the first investigation of the relationship between shoulder pathology documented on ultrasound examination and WST performances, and no analogue studies were found in the literature search. The correlation between the non-dominant USPRS and the WST, both at baseline and after one year, seems to indicate that USPRS has evidence for external validity and may have a clinical impact in predicting the performance of wheelchair athletes in some specific tasks.

Previous studies showed that chronic manual wheelchair uses severely impacts on shoulder joints [6,22,28,29]. Our study confirms the existing literature concerning the high prevalence of rotator cuff pathology in manual wheelchair users [29,30]: subacromion-deltoid bursa distension, supraspinatus tendinopathy, and supraspinatus ultrasound impingement signs were the most common shoulder ultrasound pathologic findings. Moreover, years of SCI seemed to correlate with the grade of rotator cuff tendon impairment of the dominant shoulder (USPRS score, $p < 0.005$), with PESS and USPRS scores considerably high in the participants, despite their young age. These results agree with previous literature and confirm the importance of ultrasound evaluation in wheelchair athletes, because it can identify rotator cuff pathologies more frequently than common clinical tests [31]. A lack of correlation between the ultrasound shoulder scores (USPRS) and the corresponding findings of the clinical evaluation (PESS) was not surprising, because USPRS does not evaluate all the structures examined in the physical examination, and the presence of ultrasound pathology does not often correspond to the presence of pain symptoms [22,31].

The skill tests (WST) were conducted under the same conditions in both sessions: the players sprinted on smooth terrain in a sports hall, using their defensive wheelchair chair. The presence of statistical correlation between the baseline results and those obtained after one year for both 20 m sprint ($p < 0.001$) and the 30 m figure-of-eight sprint ($p < 0.05$) proves that these results are reliable. However, no correlation was found between the performance tests and PESS. Probably, unlike the severity of shoulder pathology, the presence of low-intensity shoulder pain at rest or during physical testing does not influence the results of the WST. For this reason, it could be useful to perform a routine shoulder ultrasound in wheelchair athletes to rule out the presence of shoulder pathology.

This study had several limitations. Firstly, the small sample size due to the difficulty to enroll quadriplegic rugby athletes without any history of shoulder traumatic injury who play using the same type of sport wheelchair. Moreover, the participants were only male. Another limitation was the absence of a control group of sedentary individuals with the same demographic and clinical characteristics. Lastly, our study only related clinical, ultrasonographic and performances parameters to each other, without evaluating the possible correlations with biomechanical parameters and kinematic data.

6. Conclusions

This study suggests that dominant shoulder joint and rotator cuff muscle damage may be affected by chronic manual wheelchair use, while the non-dominant shoulder joint conditions seem related to the performance on the WST. Further studies are needed to confirm these results and to combine them with different biomechanical and kinematic parameters. Moreover, it would also be important to better understand the factors determining the wheelchair athletes' performance and the influence of the dominant and non-dominant limb during wheelchair propulsion.

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