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Original research

Ultrasound-detected connective tissue involvement in acute muscle injuries in elite athletes and return to play: The French National Institute of Sports (INSEP) study

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ABSTRACT

Objectives: Previous MRI studies showed that involvement of connective tissue in muscle injuries may prolong recovery times. The relevance of ultrasound assessment of connective tissue involvement as a prognostic factor is unknown. The aim was to test the hypothesis that ultrasound-detected connective tissue involvement in acute muscle injuries are related to longer recovery times.
Design: Cohort study.
Methods: Seventy consecutive elite athletes from the French National Institute of Sports (INSEP) sustaining an acute muscle injury showing positive findings on ultrasound at baseline were included. Ultrasound was systematically performed within 7 days after the injury for the assessment of severity (grades 1–4) and type of injury in regard to the absence (M injuries) or presence (C injuries) of connective tissue involvement. The differences in the mean time needed to return to play (RTP) between the different grades and types of injury were assessed using multiple non-parametric tests.
Results: When considering the overall grades independently of the type of injury (M or C), an increase in the mean time needed to RTP was observed with the increase of grades ($p < 0.0001$). The same relationship was found when considering grades from M and C injuries separately, with higher grades of injuries exhibiting longer times needed to RTP ($p < 0.0001$). Longer times needed to RTP were observed in athletes demonstrating C injuries in comparison to the ones exhibiting M injuries overall ($p = 0.002$).
Conclusions: Ultrasound-detected connective tissue involvement in acute muscle injuries are related to longer times needed to RTP, especially when disruption is detected.

Practical implications

- Overall, muscle injuries exhibiting connective tissue involvement depicted using ultrasound (C injuries) are related to longer times needed to RTP in comparison with injuries without such involvement (M injuries).
- Considering only muscle injuries with connective tissue involvement seen on ultrasound (C injuries), those exhibiting discontinuity of the involved connective tissue are related to longer recovery times than those without discontinuity.
- Our study supports the existing limited evidence that connective tissue involvement in muscle injuries are related to longer recovery times, and such involvement might be detected using ultrasound, which is relatively inexpensive and easily accessible compared to MRI.

1. Introduction

Acute muscle injuries are responsible for a large part of time lost to competition in elite athletes.[1,4,5] Current evidence regard-

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ing prediction of the time needed to return to play (RTP) based on imaging features is mainly related to hamstring research, with studies suggesting that a number of magnetic resonance imaging (MRI) findings are associated with the amount of time needed before RTP.[6,7,14] However, there are discrepancies in the literature regarding the predictive effect of some MRI features, with the use of MRI being contested by previous publications that could not reproduce the same results as previously published.[17,19,20]

Some studies shed light on the potential prognostic value of intramuscular connective tissue involvement in acute muscle injuries. Two studies showed evidence that MRI-detected intramuscular tendon involvement in hamstring injuries was associated with a delay in the time needed to RTP,[9,10] and such feature was even included in a recent MRI classification system of muscle injuries, the British Athletics Muscle Injury system.[21] More recently, a prospective MRI study demonstrated that mainly full-thickness disruption and waviness of the intramuscular tendon in hamstring injuries was related to longer recovery times, but a limited prognostic value was found if taking into account any intramuscular tendon involvement.[12] Furthermore, another MRI study demonstrated that connective tissue involvement in calf muscle injuries can be used to estimate the time needed to RTP.[11]

Compared to MRI, ultrasound is relatively inexpensive and easily accessible, being widely used by many sports medicine teams in the diagnosis and follow-up of muscle injuries in elite athletes. Ultrasound provides a greater spatial resolution than MRI, allowing for detailed assessment of proximal and distal connective tissues in skeletal muscles, such as intramuscular tendon as well as intra- and peri-muscular aponeurosis. Compared to MRI, there is paucity of data regarding the clinical relevance of ultrasound findings in acute muscle injuries, with controversial results regarding their prognostic value.[8,22] Furthermore, no previous ultrasound studies attempted to specifically identify involvement of muscular connective tissues in acute muscle injuries and its relationship with recovery times in athletes.

In order to demonstrate the prognostic value of ultrasound in assessing acute muscle injuries, we aimed to assess the relationships between ultrasound features of muscle injuries and the time needed to RTP in a sample of elite athletes followed at the French National Institute of Sports (INSEP), including ultrasound features of connective tissue involvement. We tested the hypothesis that muscle injuries exhibiting connective tissue involvement are associated with longer recovery times when compared to those without such involvement. Secondarily, we also tested the hypothesis that higher grades of ultrasound-detected injuries are related to longer recovery times.

2. Methods

Seventy consecutive elite athletes from several sports at INSEP were retrospectively included in our study from 2011 to 2014 if they sustained an acute muscle injury showing positive findings on ultrasound at baseline. Ultrasound was systematically performed at the department of radiology of INSEP within 7 days after the injury. Clinically, we defined acute muscle injuries as those where athletes complained of acute pain in a given muscle group, which immediately prevented the athlete from any activity in training or competition. Only muscle injuries from an indirect (intrinsic) mechanism were included in our study. Athletes were excluded in case of history of previous injuries involving the same muscle group affected by an acute injury. All athletes included had follow-up data regarding the length of time to RTP after muscle injuries. Ethical approval was obtained from the local Institutional Review Board which waived informed consent due to the retrospective nature of the study.

Table 1
The INSEP ultrasound classification of muscle injuries including severity (grades 1–4) and type (M or C) of injuries.

Type of injury	M injuries (normal ultrasound appearance of the adjacent connective tissues)	C injuries (abnormal ultrasound appearance of the adjacent connective tissues)
Grades		
1	Intramuscular ill-defined areas of increased echogenicity without architectural distortion at the myo-connective junction	Connective tissue exhibiting thickening and ill-defined contours without architectural distortion at the myo-connective junction. No connective tissue discontinuity.
2	Ill-defined areas of increased echogenicity with architectural distortion at the myo-connective junction, no visible detachment of muscle fibers, no adjacent hematoma	Connective tissue exhibiting thickening and ill-defined contours with architectural distortion at the myo-connective junction. No connective tissue discontinuity.
3	Partial detachment of muscle fibers at the myo-connective junction with adjacent hematoma	Partially ruptured connective tissue with or without adjacent hematoma
4	Complete detachment or rupture at the myo-connective junction with major retraction	

All ultrasound examinations were performed by a single musculoskeletal radiologist with over 10 years experience in sports medicine imaging. Ultrasound of the muscle group affected by injury was performed using an Aplio XG (Canon Medical Systems, Europe B.V.), with a 8–12 MHz linear probe. The region of interest (representing the region of maximal pain and tenderness as identified by the athlete) was systematically examined using transverse and longitudinal scanning with the involved muscle group fully relaxed (at rest). The radiologist considered only the primary acute injury, the one exhibiting the greater extent and severity for each athlete. Bilateral examination was systematically performed for all muscle injuries detected. The longitudinal and transverse images demonstrating the greater severity of injury were selected and saved in our Picture Archiving and Communication System (PACS). The specific muscle involved (related to the images saved) was also recorded. For the purpose of this study and to allow for a second independent assessment of ultrasound images, only images acquired with muscles at rest were included for the assessments.

All muscle injuries detected on ultrasound were graded according to the INSEP classification system of acute muscle injuries.[23] This system takes into account two distinct types of intrinsic muscle injuries: “M” injuries, representing injury at the myo-connective junction but the adjacent connective structures (intramuscular tendon, intra- or peri-muscular aponeurosis) exhibit a normal ultrasound appearance; and “C” injuries, representing involvement of the adjacent connective tissues. Since recent studies showed that the size (extent) of muscle injuries does not represent a prognostic factor when adjusting for confounders,[16–18] the size of ultrasound abnormalities was not taken into account in the classification system used in this study. For each injury type detected on ultrasound (M or C), three different grades (1–3) of severity are described in detail in Table 1. Grade 4 injuries represent a complete detachment or rupture at the myo-connective junction with major retraction, with no distinction between M and C injuries. Further, a second musculoskeletal radiologist with over 30 years experience in sports medicine independently reviewed all longitudinal and transverse ultrasound images saved initially in our PACS. The second reader was blinded to the initial report including the classification of each muscle injury, and also graded each injury according to the same scoring system.

All elite athletes included in our study followed the same treatment protocol at INSEP, adapted for each muscle group involved. The rehabilitation program was considered as successfully completed when sports-specific activities could be performed by the athlete without any restriction or pain. For each athlete, the time needed to RTP was noted by the sports medicine physician as the number of weeks between each acute muscle injury (day zero) and the return to unrestricted activity in training or competition. The supervising sports medicine physician gave the definite clearance for RTP.

We tested if there were differences in the time needed to RTP (in weeks) between the different grades of acute muscle injuries detected in our cohort using ultrasound. Further, we tested if there were differences in RTP between "M" and "C" injuries detected, including data on the whole sample of athletes, on the most common sport only, and on the most common muscle group affected only. The non-parametric Mann–Whitney and Kruskal–Wallis tests were used to assess the differences in RTP between the different groups and grades of muscle injuries. The Bonferroni correction method was applied when multiple comparisons were performed. The hypothesis log-rank test and Kaplan–Meier plots were used to compare the means of time needed to RTP in the different groups and grades of injuries. The inter-reader reliability of ultrasound assessments was evaluated using kappa statistics. Statistical significance was set at 0.05. All analyses were performed using the SAS software version 9.4 (SAS Institute, Cary NC).

3. Results

Seventy elite athletes sustaining an acute muscle injury were included, one injury per athlete. The mean age was 27.8 years (±6.1; range 22–55) and 65.7% of athletes were male (N = 46). The majority of muscle injuries affected track and field athletes (N = 25, 35.7%) followed by rugby players (N = 18, 25.7%), with a variety of sports related to the remaining athletes including football (N = 5), judo (N = 5), basketball, pentathlon, and fencing (N = 3 each), boxing, tennis, and water polo (N = 2 each), field hockey and jiu-jitsu (N = 1 each). From 70 injuries assessed on ultrasound, there were 31 hamstring injuries (44.3%), 11 calf injuries (15.7%), 10 quadriceps injuries (14.3%), 6 adductors injuries (8.6%), and 1 gluteus maximus injury (1.4%), for a total of 59 injuries affecting muscles from the lower limbs (84.3%). Muscles from the arm (N = 5, 7.1%) and the abdominal wall (N = 4, 5.7%) were the most commonly affected by injuries outside the lower limbs.

Regarding the classification of muscle injuries on ultrasound, 52 were classified as type M injuries (74.3%) and 18 as type C injuries (25.7%). There were no differences in age between the athletes exhibiting M injuries (30.7 years ± 6.5) and those exhibiting C injuries (30.8 years ± 4.5). However, a difference was observed in terms of gender, with 61.5% (N = 31) males in the "M injuries" group and 77.8% (n = 14) males in the "C injuries" group. Twenty-four injuries were classified as grade 1 (34.3%), 34 as grade 2 (48.6%), and 12 as grade 3 (17.1%). No grade 4 injuries were found in our cohort. From 52 type M injuries, 24 were grade 1M (34.3%), 22 were grade 2M (31.4%), and 6 were grade 3M (8.6%). From 18 type C injuries, 12 were grade 2C (17.1%) and 6 were grade 3C (8.6%). No grade 1C injuries were found. The inter-reader reliability (kappa) for each specific injury grade was 0.45 ($p < 0.0001$), and for the type of injury (M or C) was 0.65 ($p < 0.0001$).

When considering the overall grades (1–3) independently of the type of injury (M or C), an increase in the mean time needed to RTP was observed with the increase of grades ($p < 0.0001$ for all comparisons performed; Table 2; Fig. A1 in Appendix 1). The same relationship was found when considering grades from M and C injuries separately, with higher grades of injuries exhibiting longer times needed to RTP ($p < 0.0001$ for all comparisons performed; Table 2; Fig. A1 in Appendix 1). Longer times needed to RTP were observed in athletes demonstrating C injuries in comparison to the ones exhibiting M injuries (all C injuries vs. all M injuries; $p = 0.002$; Table 2; Fig. A1 in Appendix 1). Although we observed a higher mean time needed to RTP for each grade of C injuries when compared to each grade of M injuries (2C vs. 2M; 3C vs. 3M), these differences were not statistically significant, and the standard deviation values obtained indicate overlap (Table 2).

Table 2
Differences in the mean time needed to return to play (RTP) when considering the overall grades (1–3) and each grade for each type of injury (M or C) detected on ultrasound ($p < 0.0001$ for all statistical comparisons performed for the overall grades and for grades within each type of injury). Differences in RTP between all M injuries vs. all C injuries were statistically significant ($p = 0.002$).

Overall grades	RTP (weeks) Mean ± SD	Min–max	95%CI
1 (n = 24)	2.2 ± 1.1	0–4	1.7, 2.6
2 (n = 34)	4.6 ± 1.9	2-9	3.9, 5.2
3 (n = 12)	11.1 ± 3.6	6-17	9.1, 13.1
M injuries Grades	RTP (weeks) Mean ± SD	Min–max	95%CI
1 (n = 24)	2.2 ± 1.1	0–4	1.7, 2.6
2 (n = 22)	4.1 ± 1.6	2–8	3.4, 4.8
3 (n = 6)	10.2 ± 3.8	6.7–17	7.2, 13.2
All M injuries (n = 52)	3.9 ± 1.4	0–17	3.5, 4.3
C injuries Grade	Mean ± SD	Min–max	
2 (n = 12)	5.4 ± 2.3	3–9	4.1, 6.7
3 (n = 6)	11.8 ± 3.6	6–16	8.9, 14.7
All C injuries (n = 18)	7.6 ± 2.9	3–16	6.3, 8.9

Considering athletes from track and field only, the most common sport in our sample (N = 25, 35.7%), we found that longer times needed to RTP were observed in athletes exhibiting C injuries (7.8 mean weeks ± 3.8; 95%CI 5.6, 10.0) compared to those exhibiting M injuries (4.8 mean weeks ± 2.6; 95%CI 3.5, 6.1); $p = 0.03$. For the other sports related to the remaining athletes included, the low number of athletes in each sport and consequently the lack of statistical power do not allow for additional analyses regarding the relationship between the types of injuries and recovery times.

Considering athletes exhibiting hamstring injuries only, the most common muscle group affected by injury in our sample (N = 31, 44.3%), we found that longer times needed to RTP were observed in athletes exhibiting C injuries (7.9 mean weeks ± 4.9; 95%CI 5.3, 10.5) compared to those exhibiting M injuries (4.1 mean weeks ± 2.3; 95%CI 3.1, 5.1); $p < 0.01$. For the other muscle groups affected, the low number of athletes and consequently the lack of statistical power do not allow for additional analyses regarding the relationship between the types of injuries and recovery times.

4. Discussion

In this sample of elite athletes sustaining an acute muscle injury assessed on ultrasound, we found that higher grades of injury exhibited longer recovery times when considering the general grades (1–3) as well as when comparing different grades of the same type of injury (M or C). Furthermore, considering only the type of injury, we found that recovery times were longer for athletes exhibiting C injuries in comparison with those having M injuries in general. However, when specifically comparing the same grades from different types of injury (2M vs. 2C and 3M vs. 3C), no significant differences were found in the time needed to RTP. Finally, we report a moderate agreement between both radiologists when considering each specific grade from the classification system of muscle injuries assessed on ultrasound. However, a substantial agreement between radiologists was found when considering the type of muscle injury (M or C).

Previous MRI studies highlighted the potential clinical relevance of muscle injuries affecting connective tissues such as the intramuscular tendon involvement in hamstring injuries[9,10] and rectus femoris injuries,[15] as well as connective tissue involvement in calf injuries (tendon, aponeurosis, and epimysium).[11] These studies showed that injuries affecting connective tissues demonstrated longer recovery times than those without such involvement, especially in cases of disrupted and/or retracted connective structures. A recent prospective MRI study evaluated the presence of intramuscular tendon involvement in hamstring injuries and the relationship with the time needed to RTP.[12] The authors found that hamstring injuries exhibiting full-thickness disruption of the intramuscular tendon and the presence of a "waviness" pattern of the intramuscular tendon were associated with slightly longer recovery times compared with injuries without intramuscular tendon involvement. However, the authors found that partial-thickness disruption of the intramuscular tendon did not substantially increase the time needed to RTP. Because the slight prolonged RTP and considerable overlap between groups compared, the authors concluded that the clinical relevance of intramuscular tendon involvement was limited in regard to prognosis.[12]

Ultrasound allows visualization of muscular architecture at in-plane resolutions of under 200 μm and section thickness of 0.5–1.0 mm, which exceeds current MRI.[24] Compared to MRI, it also offers a number of distinct advantages: it is fast, relatively cheap, easier for patients, and allows dynamic evaluations. Furthermore, ultrasound can demonstrate the muscle structure and other relevant anatomy surrounding an injury that can often be obscured by edema on MRI,[8] including high-resolution assessment of intra- and peri-muscular connective tissues, intramuscular tendon, and intramuscular aponeurosis. Previous studies used ultrasound to evaluate features of acute muscle injuries and their relationship with RTP.[8,22] A longitudinal study of acute hamstring injuries comparing ultrasound and MRI features evaluated the correlations between imaging features and recovery times. The authors found the cross-sectional area of the injury and the presence of an intramuscular hematoma depicted on ultrasound were positively correlated to the time needed to RTP.[8] Another study evaluating the prognostic value of ultrasound features of hamstring injuries in soccer players showed no significant differences in the time needed to RTP between athletes with and without ultrasound abnormalities.[22] Further, the same study found no correlation between the length of injuries and the time needed to RTP.

None of the previous ultrasound studies specifically assessed connective tissue involvement in muscle injuries and its relationship with RTP. To the best of our knowledge, our study is the first to take into account ultrasound features of connective tissue involvement in muscle injuries as prognostic factors. The classification system used in our study[23] distinguishes injuries exhibiting ultrasound involvement of intra- and perimuscular connective tissues (C injuries) from those without such involvement (M injuries). Considering all grades of injuries detected in our sample, we found that athletes with C injuries exhibited longer (mean) recovery times than those with M injuries (3.7 weeks mean time longer for C injuries). This supports the existing evidence from previous MRI studies,[9–11] reinforcing the idea that connective tissue involvement in muscle injuries has some prognostic value. Longer recovery times related to C injuries were also demonstrated when considering athletes from track and field only (most common sport in our sample), as well as when considering athletes exhibiting hamstring injuries only (most common muscle group affected in our sample), with the global mean recovery times for different grades of C injuries being comparable to the ones from a previous study includ-

(a)

(b)

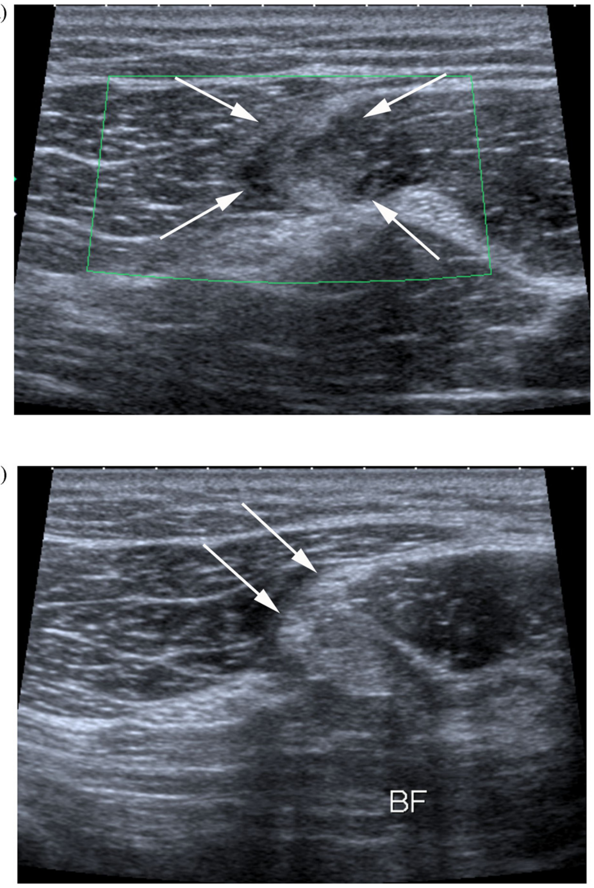

Fig. 1. (A) Ultrasound-detected grade 3C injury at the proximal myo-tendinous junction of the long head of the biceps femoris muscle in a 21-year-old male sprinter. Partial disruption of the intramuscular tendon is depicted (arrows), exhibiting ill-defined margins, hypoechogenicity and focal central thinning consistent with focal partial discontinuity. (B) A normal ultrasound appearance of the tendon in another elite athlete for comparison, exhibiting well-defined margins and high echogenicity, with preserved thickness at the proximal myotendinous junction (arrows). (A and B) Transverse views.

ing only track and field athletes with hamstring injuries.[10] We also demonstrated that injuries with disruption of the involved connective tissue (grade 3C; Fig. 1) exhibited even longer recovery times when compared with those without disruption of the involved connective tissue (grade 2C) (6.4 weeks mean time longer for 3C injuries). This also supports the results from previous MRI studies, which demonstrated that injuries exhibiting disruption and/or retraction of the involved connective tissue were related to longer mean times needed to RTP.[10–12] When directly comparing the same grades of different types of injuries, we found a slight increase in the mean time needed to RTP for C injuries (1.3 weeks mean time difference between 2C and 2M; 1.6 weeks mean time difference between 3C and 3M). However, the standard deviation values found indicate overlap between these groups, and such differences are difficult to interpret. Higher grades of ultrasound-detected injuries were related to longer recovery times considering M injuries only, as well as the overall grades regardless of the type of injuries.

Connective tissue involvement in muscle injuries, mainly connective tissue disruption, seems to be the one morphological feature exhibiting some clinical relevance in terms of recovery times of athletes and our study demonstrated that ultrasound assessment of muscle injuries is capable of depicting such involvements, which lead to longer recovery times in our sample. Injuries affecting muscular connective tissues such as the intramuscular tendon, the perimuscular aponeurosis, or the intramuscular aponeurosis seem to lead to a dysfunction in its biomechanics, as such tissues act not only as an anatomical support to the muscular tissue but also in transmitting both tensile and shear loads generated by muscles, transmitting force from a segment to another.[25,26] Thus, alterations in the structure of such tissues (mainly disruption) would impair these important biomechanical functions, which could explain why connective tissue involvement in muscle injuries is related with longer recovery times. Compared to MRI, ultrasound may be easily implemented in sports medicine facilities, even within the field, and be used to evaluate connective tissue integrity in acute muscle injuries, providing thus some prognostic input to athletes and physicians.

Our study has some limitations. As we included only elite athletes, the results of our study may not reflect the general population. Also, the supervising sports medicine physicians responsible for the definite clearance for RTP were not blinded to the results from the initial ultrasound performed. This included knowledge about the presence or absence of connective tissue involvement. However, at the time of the inclusion period (2011–2014), there was no strong evidence that general connective tissue involvement in different muscle groups was associated with longer recovery times in athletes, with only one publication available assessing the intramuscular tendon involvement in the hamstring.[9] The time needed to RTP could also be influenced by the athlete's motivation to RTP and pressure to compete exerted by the teams. Further, we acknowledge that the time needed to RTP may vary during preseason, season, and postseason. Although the initial treatment protocol for muscle injuries was similar among the athletes included, the rehabilitation program was further adapted for each muscle group affected and sport-specific activities were implemented during the program, which might have influenced our results. The inter-reader reliability assessment was not performed following a second and independent real repeated examination but rather a re-reading of the images documented in the first place. Finally, we included injuries from different muscle groups from elite athletes practicing various sports, and since each muscle group has different anatomy and function related to sport-specific activities, this might have played a role in the results.

5. Conclusion

Ultrasound-detected connective tissue involvement in acute muscle injuries of elite athletes are related to longer times needed to RTP, especially when a disrupted connective tissue (intramuscular tendon or aponeurosis) is detected, which is in accordance to previous MRI studies. Radiologists performing ultrasound in acute muscle injuries should drive their attention to the connective tissue integrity near areas of injury, which may potentially estimate the duration of rehabilitation in elite athletes. Further prospective studies applying ultrasound in injuries of specific muscle groups and specific sports are necessary to confirm the prognostic value of ultrasound-detected connective tissue involvement.

Acknowledgments

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Appendix 1.

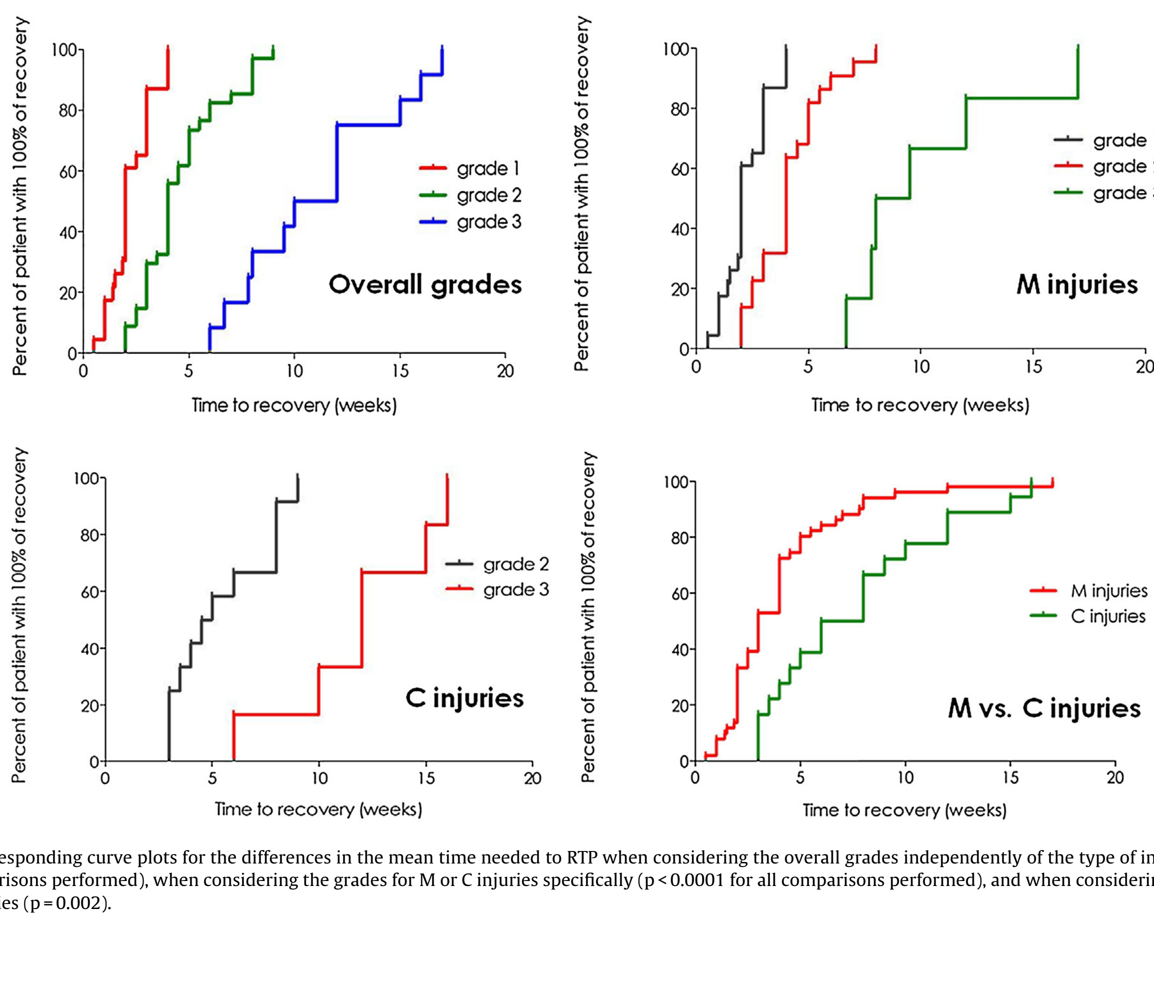

Fig. A1. Corresponding curve plots for the differences in the mean time needed to RTP when considering the overall grades independently of the type of injury ($p < 0.0001$ for all comparisons performed), when considering the grades for M or C injuries specifically ($p < 0.0001$ for all comparisons performed), and when considering all M injuries vs. all C injuries ($p = 0.002$).

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