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ORIGINAL PAPER

Functional impairment after successful surgical reconstruction for proximal hamstring avulsion

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Abstract

Purpose Surgical refixation procedures after hamstring avulsion injuries show satisfying to excellent outcome results. However, for post-operative evaluation so far, used outcome scores were partially not injury-specific, heterogeneous, difficult to compare, and possibly overestimated due to ceiling effects. A new injury-specific assessment tool has recently been published, potentially depicting more realistic outcome results. Thus, the aim of our study was to evaluate patients after hamstring refixation surgery using previously utilized as well as the new Perth hamstring assessment tool (PHAT).

Methods A series of operated hamstring injuries were retrospectively evaluated using the PHAT as well as the widespread, customized Lower Extremity Functional Scale (C-LEFS) and the customized Marx score (C-Marx). Scores as well as potential ceiling effects were evaluated individually, and compared and correlated to each other.

Results Sixty-four patients were enrolled into the survey. Forty-nine questionnaires (76%) could be evaluated. The mean total PHAT score (0–100) after 28 months (SD ± 17.0) was 74.1 (SD ± 22.5) points. Mean total C-LEFS (0–80) revealed 61.4 (SD ± 18.1) points, and the mean total C-Marx score (20) was 19.4 (SD ± 1.6) points. Pearson's correlation between the individual questionnaires was high between the PHAT and the C-LEFS ($r = 0.81$) and low between the PHAT and C-Marx ($r = 0.52$) and between C-LEFS and C-Marx ($r = 0.48$).

Conclusion The presented study confirms good subjective functional outcomes after surgical intervention of hamstring avulsions in all scores. Nevertheless, using the PHAT, residual complaints are more common than often described in previous studies interpreting "conventional" scores. For future decision and patient guidance, more studies using injury-specific assessments such as the PHAT in combination with objective measurements are eligible.

Keywords Proximal hamstring surgery · Tendon refixation · Outcome measurement · Return to activity

Introduction

Hamstrings injuries are among the most common sporting injuries in professional athletes as well as in recreational athletes [1–4]. Generally, hamstring strains affect the mid muscular portion or the myotendinous junction, whereas proximal, tendinous hamstring ruptures with avulsion of the conjoint tendons origin from the ischial tuberosity are far more debilitating [4–6]. Here, intending to regain lost function, operative treatment with refixation of the ruptured tendons is recommended as the therapeutic method of choice [2, 4–11]. Despite several publications on this topic, high level supporting evidence regarding clinical and/or functional outcomes is still under discussion [10]. Causative, most outcome descriptions show a wide heterogeneity of outcome measurements, results, and a lack of comparability [2, 4, 9, 10].

This can be exemplified by three recent systematic reviews [2, 4, 10] which consistently reasoned the benefit of surgical repair despite a complication rate of almost 25% [10]. Furthermore, the low methodological quality of most included studies was described, interpreting the named vast heterogeneity of outcome measures in partially a small number of patients [9, 10, 12]. In fact and of capital importance, the majority of the so far utilized scoring tools were either non-specific to hamstring injuries but somehow "adapted," were not validated or even both [11,

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13–17]. Hence, in part previous studies and scores could not avoid an eventual misgrading of the investigated post-operative outcome, potentially resulting in overestimated and thus false results, a so-called ceiling effect [7].

Blakeney et al. (2017) just published the new Perth Hamstring Assessment Tool (PHAT), which is a hamstring-injury-specific, validated, self-reported outcome score with high internal consistency and a high reproducibility. Prospectively investigating 72 [7] and 96 [18] consecutive proximal hamstring repairs, they were able to implement and test a valid, reliable and comparable assessment tool in a large number of patients, concluding more realistic and comparable outcomes after surgery [7, 18].

However, so far, the PHAT score was only described to be implemented and to present own surgical results but not to be compared with other, previously used scores in order to unmask potential flaws of earlier investigations.

Thus, the aim of the present study was to evaluate and display the outcome of surgical repair in an own, comparably large series of hamstring injuries using the new validated PHAT score as well as two common, frequently used, non-validated customized scores.

We hypothesized that generally, the functional outcome after surgical intervention using the PHAT score makes surgery still recommendable—though the occurrence of functional impairments using a specific score might appear more often than so far assumed in previous studies utilizing conventional scores.

Materials and methods

Data collection

Initially, for this retrospective case-control study, the data of all patients who received operative treatment of acute, delayed, or chronic proximal hamstring avulsion between January 2011 and September 2016 in our hospital was collected. The medical records were reviewed; patient data, patient history, and surgical documentation was collected for all cases.

Similar to previous studies [1, 2], we then categorized injuries treated within four week post-trauma as acute, surgical procedures later than four week post-injury as delayed, and injuries presenting more than three month post-trauma were considered chronic.

Patients who were treated more than three months after injury (chronic), with a follow-up less than six months after surgery, or who subsequently could not be contacted due to change of contact details were excluded from the study. There was no further differentiation regarding gender, age, or trauma origin.

Corresponding to the current state of knowledge [1, 2, 6], the indication for a surgical intervention of the included cases had to be either a complete conjoint tendon rupture or an isolated biceps femoris or semitendinosous tendon rupture with a tendon retraction of two or more centimeters. All patients were surgically treated by tendon to bone-refixation of the ruptured tendons [8, 19] (the surgical procedure is described below). All surgery was performed by two senior surgeons.

All patients having met the inclusion criteria were contacted via telephone and mail to obtain their informed consent to participate in the study. All participants were asked to complete questionnaires sent to them, consisting of the Perth Hamstring Assessment Tool (PHAT) [7], the Customized Lower Extremity Functional Scale (C-LEFS) [5, 13], and the Customized Marx Score (C-Marx) [5, 13]. All completed and returned questionnaires were then evaluated. This retrospective survey does not contain any experimental studies on human participants or animals and thus meets all ethical standards described in the Declaration of Helsinki.

Surgical procedure

The surgical procedure was performed as described in several previous studies [1, 6–8, 12, 19] whereby only the most relevant steps are described here.

After pre-operative considerations (MRI evaluation, sciatic symptoms), type of injury (acute, delayed, chronic), and cosmetic aspects, a preferred skin incision was performed transversally in the subgluteal fold (acute injury, no sciatic symptoms) (Fig. 1). In delayed or chronic procedures, in the case of sciatic symptoms or a relevant proximity between the tendon stump and the sciatic nerve on MRI (Fig. 2), a longitudinal incision centered over the tendon was preferred.

During dissection of the ruptured tendon, a visual and haptic identification of the sciatic nerve was

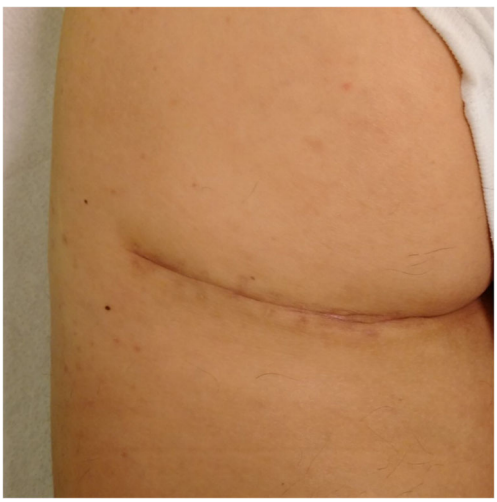

Fig. 1 Crosswise subgluteal incision for acute injuries without further noticeable problems 6 weeks after surgery

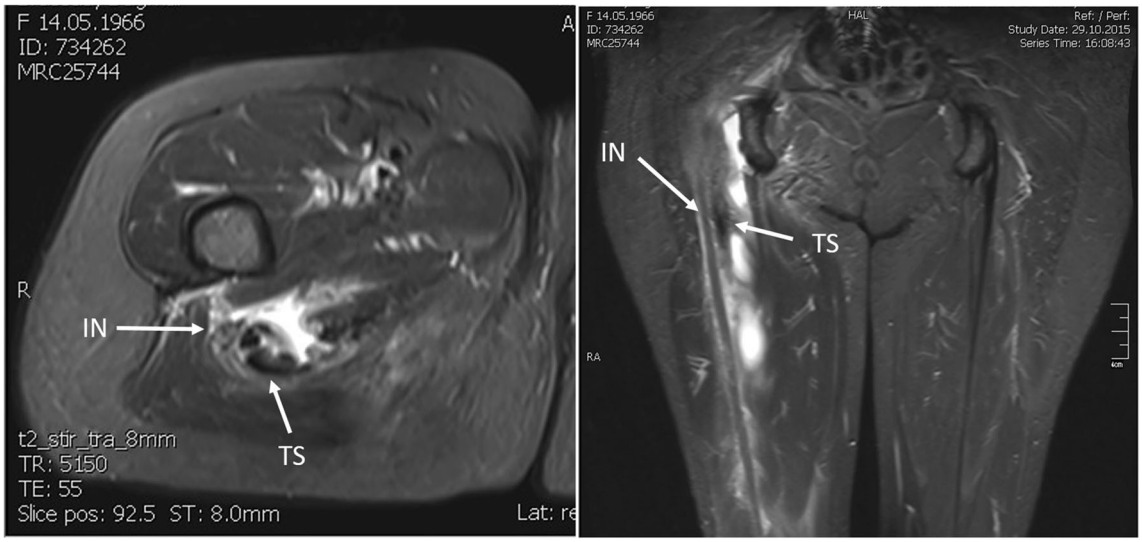

Fig. 2 Relevant proximity of the ruptured tendon stump and the sciatic nerve on axial and coronar MRI (T2Stir) in an acute injury of a 49-year-old female patient (IN ischial nerve, TS tendon stump)

performed routinely. A marking by a vessel loop or even neurolysis (Fig. 3) was only done in delayed and chronic cases or in certain cases with a complex identifiable intra-operative site.

After preparation and debridement of the ischial tuberosity, three suture anchors (upon surgeons preference: Bio FASTak®Suture anchor or Corkscrew® FT, Arthrex®, Naples, USA) were placed ascending into the ischial tuberosity respecting the tendon insertion's footprint and anatomy [8, 20]. Sutures were passed through the tendon which was then reattached from proximal to distal [8, 20] (Fig. 4).

In all cases, rehabilitation consisted of partial weight bearing on crutches for 4 weeks with subsequent increasing weight bearing load for another two weeks. Excessive active flexion and extension of the hip was prohibited for six weeks. Isometric strength training of the hamstrings was allowed eight weeks after surgery at the earliest.

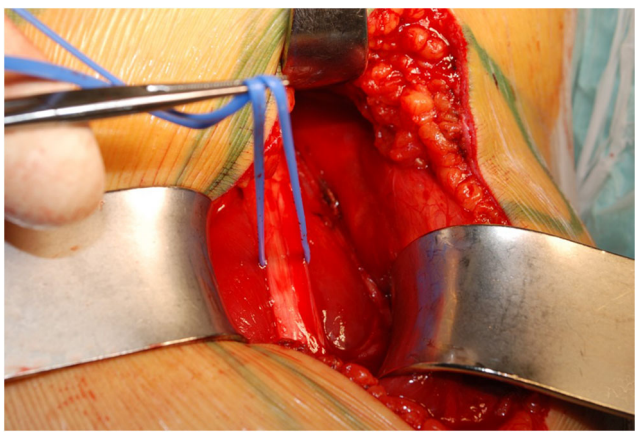

Fig. 3 Marking of the ischial nerve

Questionnaires

Perth Hamstring Assessment Tool (PHAT)

The PHAT is a new and validated scoring system which was specifically developed to evaluate the functional outcome of proximal hamstring injuries [7, 18]. The questionnaire uses a visual analogue scale to assess the patient's pain as well a categorical assessment of activity levels. Particularly subjective assessments and answers are converted into a scoring system with a total minimum score of 0 and a maximum score of 100. Ultimately, a higher score corresponds to a higher function, less residual symptoms, and less impairment respectively (Fig. 5).

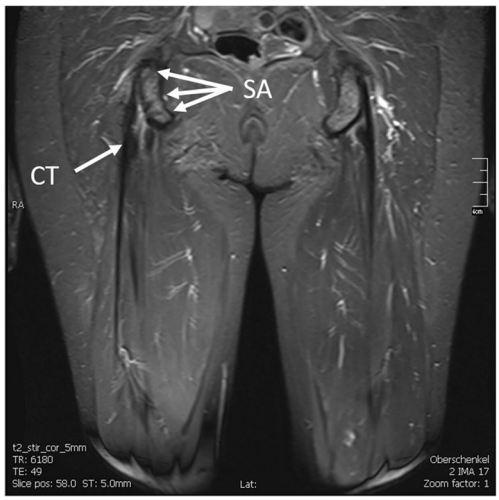

Fig. 4 Post-operative coronar MRI (T2_Stir) 12 months after surgery in the same patient as Fig. 2. (CT reattached conjoint tendon, SA suture anchors]

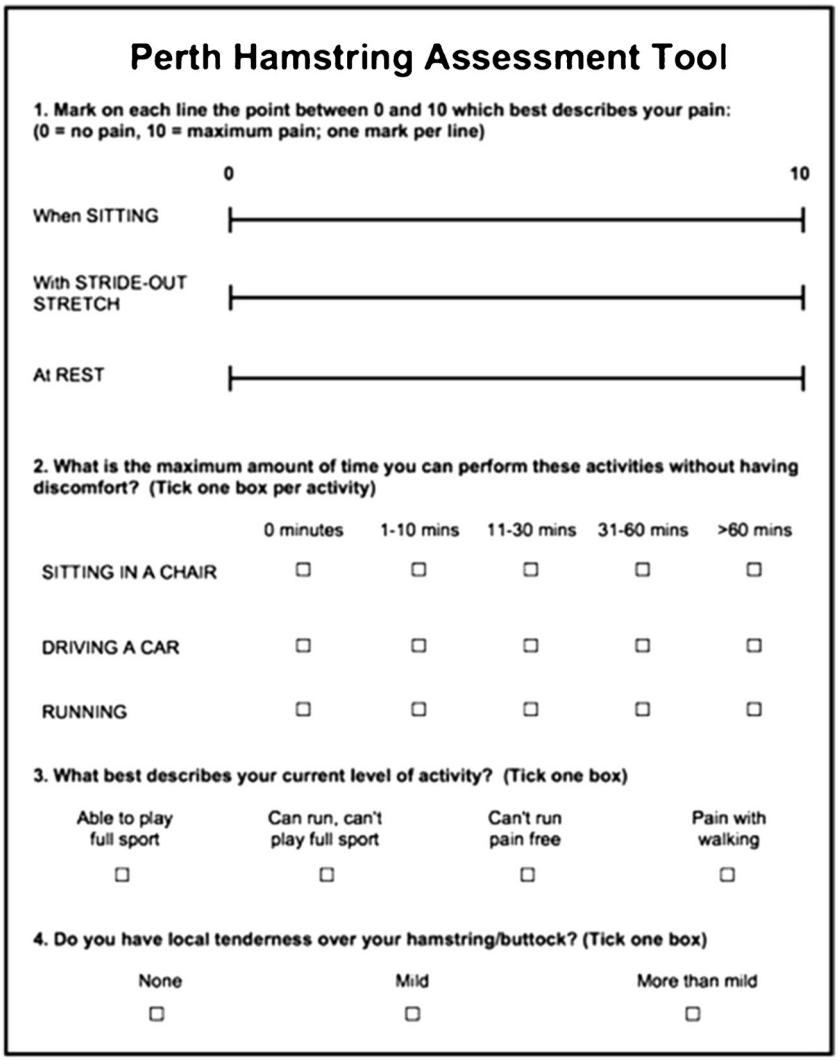

Fig. 5 Perth Hamstring Assessment Tool (from Blakeney et al. [7])

FIGURE 2 – PHAT Scoring System:
Question 1: (10 – response) for each section. Ie Pain of 9 scores 1 point
Question 2: 0 mins=0, 1-10 mins=5, 11-30 mins=8, 31-60 mins=12, >60 mins=15
Question 3: Full sport=15, Can run=10, Can't run pain free=5, Pain with walking=0
Question 4: None=10, Mild=5, More than mild=0

Customized Lower Extremity Functional Scale (C-LEFS)

The non-validated Customized Lower Extremity Functional Scale [5, 13] was developed from the validated Lower Extremity Functional Scale [21], a non-specific scoring system for general lower limb function. Here, original questions regarding general activity assessment were arbitrarily altered into questions, reflecting symptoms particular to hamstring ruptures [5, 7]. Similar to the PHAT, subjective assessment is converted into a scoring system with a total minimum score of 0 and a maximum score of 80, and a higher score reflects a better function.

Customized Marx Activity Score (C-Marx)

The original validated Marx Activity Scale is a scoring system for knee pathologies [22]. It was transferred into the Customized Marx Activity Score [1, 5] by specifying and simplifying the assessed activities to get a more specific reflection of the functional outcome for hamstring injuries. Again, a minimum score of 0 (no or bad function) to a maximum score of 20 (full function) can be achieved.

Statistical analysis

Descriptive statistics were calculated for all registered scores (PHAT, C-LEFS, C-Marx). Results of all scores allowed accuracy to 1 decimal place.

Corresponding to Blakeney et al. [7], Pearson's correlation coefficient was calculated to evaluate the correlation between the three different scores. A correlation of $r > 0.7$ was considered high, r 0.5 to 0.7 equaled a moderate correlation, r 0.3 to 0.5 a low correlation and $r < 0.3$ a negligible correlation [7, 23].

Results

During the assigned period, a total of 87 proximal hamstring injuries were treated using refixation surgery in our hospital. Finally, according to the abovementioned inclusion criteria, 64 patients with proximal hamstrings refixation were suitable for survey.

Of the 64 questionnaires sent, 49 were returned within three months, representing a response rate of 76%. All questionnaires were completed without missing out any items. The mean follow-up documented in all returned questionnaires was 28.0 months (SD ± 17.0).

Mean total PHAT-score (0–100) was 74.1 (SD ± 22.5) points. Means and standard deviations of the single assessments are displayed in Table 1.

The mean total C-LEFS (0–80) revealed 61.4 (SD ± 18.1) points, and the mean total C-Marx score (0–20) was 19.4 (SD ± 1.6) points.

Correlation between the PHAT and the C-MARX (r = 0.52), and the C-LEFS and C-MARX (r = 0.48) was low, whereas PHAT and C-LEFS showed a high correlation (r = 0.81) (Fig. 6).

Ceiling effect:

PHAT	5 patients out of 49 (10.2%) had a maximum of 100 points
C-LEFS	8 patients out of 49 (16.3%) had a maximum of 80 points
C-Marx	35 patients out of 49 (71.4%) had a maximum of 20 points

Discussion

Confirming our hypothesis, the most important finding of the current study was that there is a relevant heterogeneity of outcome results after hamstring refixation surgery dependent on the utilized investigation score. Considering and comparing the particular outcome results of the new PHAT score and the "conventional" C-LEFS and C-Marx as well as the corresponding ceiling effects, it can be concluded that previously used non-specific or non-validated scores potentially overestimate outcome results, displaying them too positively.

In contrast, the results of the specific PHAT score reveal that functional impairment even after successful surgery might be more common than admitted previously. For example, only 10.2% of all investigated patients in the current study scored a maximum of 100 points using the PHAT score, whereas almost three-fourths of the same collective accomplished a maximum of 20 points filling in the C-Marx.

Table 1 Single assessment outcomes of the PHAT score

Question	1.1	1.2	1.3	2.1	2.2	2.3	3	4	Total
Mean	7.4	7.6	8.8	11.6	12.4	11.1	9.9	5.3	74.1
SD	± 2.6	± 2.5	± 2.4	± 4.6	± 3.9	± 5.1	± 4.8	± 2.6	± 22.5

This might be due to too vague and/or unspecific outcome ratings with non-injury-specific questions and assessments which than can lead to high scores being easily achieved—although there may be few residual complaints. For example, the C-Marx questions the frequency of different daily routine activities such as walking up one flight of stairs without assistance. Of course, this needs to be regarded as one main objective after surgery—though neither does the score clarify the occurrence of complaints during such activities nor does it identify the ability for more challenging loads. Consequently high score criteria are easily met.

In general, apart from minimal discrepancies, the results of the current study evaluating the PHAT, the C-LEFS, and the C-Marx are in congruence with previous study results using the same scores [2, 4, 5, 7, 11, 13]. In particular, the results of the PHAT results support the underlying studies by Blakeney et al. [7, 18]. Their prospective investigation of 72 [7] patients revealed a mean PHAT score at 1-year follow-up of 76.7 (SD ± 16.0), which—despite a shorter follow-up—is slightly higher than the results of the current study (74.1 ± 22.5). Taking into account the reported significant mean increase of 36.4 points of the PHAT after surgical intervention [7] and assuming similar pre-operative impairments in our own patients, our outcome results similarly suggest that operative refixation should be recommended.

Numerous outcome measurements are described in literature, which display good to excellent results after hamstring surgery [2, 4, 5, 15, 24]. For example, Cohen et al. (2012) collected six different scores in 52 patients after a mean follow-up of 33 months. To use a potentially more hamstring injury-specific score, they implemented and utilized the C-LEFS and Marx score, also used in the current study. The results of their C-LEFS score revealed a satisfying mean of 71 of 80 points, irrespective of the time of surgery after trauma. Their C-Marx results even revealed a mean score of 20 points, representing the highest score possible. Though of course drawing their conclusions from the customized scores, except of claiming a lacking validation, further doubts such as presumed too positive results due to ceiling effects were not discussed. Similarly, good results were also reported by Bowman et al. (2013), revealing a C-LEFS of 66.7 ± 17 and a C-Marx score of 20.

The C-Marx results (19.4 ± 1.6) in the current study also show a compelling outcome. Nevertheless, with 71.4% of the patients achieving maximum score, again we presume a ceiling effect in our study as well as the abovementioned data, which overestimates the interventions outcomes. This scores mismatch in our study is also reflected by a comparably low correlation between the

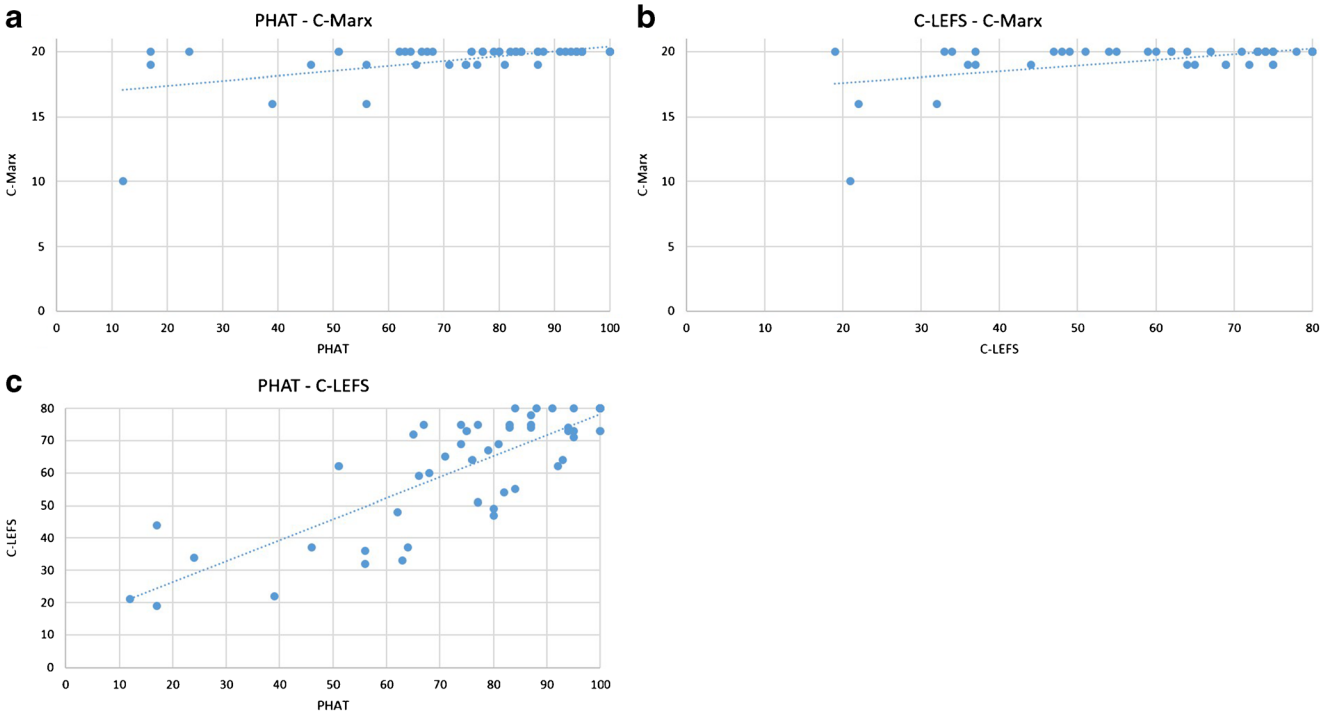

Fig. 6 Pearson's corrrelation coefficient between the singular scores. **a** PHAT, C-Marx ($r = 0.52$). **b** C-LEFS, C-Marx ($r = 0.48$). **c** PHAT-C-LEFS ($r = 0.81$)

PHAT and C-Marx ($r = 0.52$) as well as between the C-Marx and the C-LEFS ($r = 0.48$).

In contrast, results from our C-LEFS show a high correlation with the PHAT ($r = 0.81$), although our mean score outcome is lower than other existing data [5, 13]. As repeatedly mentioned, this might in part be due to the central issue of arbitrarily customized and non-validated questionnaires with potential diffculties comprehending some answer possibilities. For example, patients who do not play soccer might have difficulties answering whether they "could" play, and if so, with which degree of complaints. Thus, the outcome of the C-LEFS depends completely on the investigated population, whereas the PHAT generally addresses functional activity in an athletic and a recreational population.

Not least, often a surgical procedures outcome is rated by return to activity or return to sport rates respectively, partially also revealing impressing results [9]. For example, regarding the largest case series in the literature, Subbu et al. (2015) reported an impressive 96.4% return to sport rate to a preinjury sports activity level in 112 operated athletes at an average of 19 weeks after proximal hamstring surgery. More than half (56.3%) of the investigated patients were even classified as "high level athletes" or "elite athletes," making the study's conclusion, that the timing of surgery seems the most relevant parameter to achieve perfect results even more impressive.

Not using additional specific scores, they also described local neural symptoms in 12 patients (11%), some of whom required ongoing conservative treatment. However, the authors did not discuss whether their athletes complained about additional residual symptoms during all-day activities or when returning to sports. They also did not specify the details of how the athletes returned to play—with or without complaints, only training or on a competitive level, etc.

Considering the PHAT outcomes concerning running (question 2.3) and sport activity (question 3) in the current study in detail, the majority of patients (73.4%) were able to run 30 minutes or more without any problems, which reflects a return to sportive activity for most of operated patients. However, only 34.7% of the patients stated they were able to play full sports, probably representing their "preinjury level." In addition, only 16.3% of the patients stated they had absolutely no tenderness over their hamstring/buttocks, confirming our hypothesis that the declaration of residual complaints after surgery and thus the overall outcome inevitably depends on the quality of the assessment tool.

There are several limitations of this study. First, this is a retrospective survey with a respondence rate of "only" 76%, including patients with an inconsistent follow-up and with no comparison to preinjury results of the used scores. It would have been preferable—in congruence with previous publications as well as in congruence to the publication by Blakeney et al. (2017)—to register the used evaluation scores after a preassigned period of time as well as before surgery.

However, it was not the authors purpose to display a surgical procedures outcome after a certain rehabilitation period. A longer follow-up might improve functional results in comparison to a preassigned follow-up of one year. However, results from a short follow-up of six months might also improve over time, and compensate this inconsistency.

Furthermore, the most relevant score, the PHAT, was published as recently before our investigation. Due to our intention to include an appropriate amount of patients despite a rare incidence of hamstring tendon injuries, a minimum follow-up of six months and a main focus on the comparison of the "new" PHAT and previous scores, our investigation could only be conducted retrospectively. Secondly, the presented study was a survey based on a subjective assessment by questionnaires, and no objective measurements like strength evaluations or agility tests were performed. As it was intended to display residual subjective impairment using a specific scoring tool in comparison to previous studies, additional objective measurements were regarded eligible but not mandatory.

In conclusion, the presented study confirms our hypothesis that a surgical intervention after hamstring avulsion injuries is recommended—although residual complaints despite surgical success is more common than so far admitted and described. Further controlled investigations of the subjective, functional outcome using validated and specific outcome measurements like the PHAT after hamstring surgery in combination with objective outcome measurements such as strength or agility are required in order to improve assessments and thus to specify indications and expectations of different patients after hamstring avulsion injuries.

Compliance with ethical standards

This retrospective survey does not contain any experimental studies on human participants or animals and thus meets all ethical standards described in the Declaration of Helsinki.

Conflict of interest The authors declare that they have no conflicts of interest.

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