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**TITLE PAGE**

# Validity of the SPEx sports injury surveillance system for time-loss and medical attention injuries in sports

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**ABSTRACT**

The accurate measurement of sport exposure time and injury occurrence is key to effective injury prevention and management. Current measures are limited by their inability to identify all types of sport-related injury, narrow scope of injury information, or lack the perspective of the injured athlete. The aims of the study were to evaluate the proportion of injuries and the agreement between sport exposures reported by the SMS messaging and follow-up telephone part of the SMS, Phone, and medical staff Examination (SPEx) sports injury surveillance system when compared to measures obtained by trained on-field observers and medical staff (comparison method).

We followed 24 elite adolescent handball players over 12 consecutive weeks. Eighty-six injury registrations were obtained by the SPEx and comparison methods. Of them 35 injury registrations (41%) were captured by SPEx only, 10 injury registrations (12%) by the comparison method only, and 41 injury registrations (48%) by both methods. Weekly exposure time differences (95% limits of agreement) between SPEx and the comparison method ranged from -4.2 to 6.3 hours (training) and -1.5 to 1.0 hours (match) with systematic differences being 1.1 hours (95% CI 0.7 to 1.4) and -0.2 (95% CI -0.3 to -0.2), respectively. These results support the ability of the SPEx system to measure training and match play exposures and injury occurrence among young athletes. High weekly response rates (mean

83%) indicate that SMS messaging can be used for player measures of injury consequences beyond time-loss from sport. However, this needs to be further evaluated in large-scale studies.

**KEYWORDS: ATHLETIC INJURY, SURVEILLANCE, VALIDATION STUDY, INJURY REGISTRATION, HANDBALL**

## INTRODUCTION

Sports injuries are a common (Frisch et al. 2009) and costly health problem in youth (Hupperets et al. 2010; Collard et al. 2011). Thus, developing injury prevention strategies is a priority. Effective prevention requires an understanding of the type (e.g., medical, time-loss), occurrence, etiology, and consequences of sports injuries through valid surveillance (van Mechelen et al. 1992; Finch 2006).

Traditionally, sport injury surveillance research has focused on the identification of injuries that result in medical attention or time-loss from sport. For example, Emery et al. (2005) developed and validated an injury surveillance system that used trained observers to measure sport exposure hours, time-loss and medical attention injuries. The benefits of this approach include the precise identification of time-loss and medical attention injuries and medical staff examination of injured players. However, this is a time- and resource-intensive method that may not be feasible in many sporting environments. Moreover, this approach may result in underreporting of other injury types (e.g., overuse injuries) and provides limited information about the player's perspective on consequences of injury beyond time-loss or the need for medical attention (Clarsen et al. 2013).

The Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire is a self-report injury surveillance tool developed to address many of the limitations of observer reporting (Clarsen et al. 2013). A questionnaire is delivered via e-mail and is based on four fundamental questions applied to different body regions defined a priori. These questions inquire about the extent to which problems in a particular body region affected a player's sports participation (question1), training volume (question 2), performance (question 3), and pain (question 4).

Specifically, the OSTRC tool purports to improve the identification of injuries and physical complaints missed by traditional approaches, as well as measures the consequences of injury based on self-reported participation and performance limitations rather than time-loss (Clarsen et al. 2013; Clarsen et al. 2014). However, the large volume of questions needed to address multiple injuries (Andersen et al. 2013; Clarsen et al. 2013) and reliance on e-mail delivery may be problematic in youth and community sport where athletes may be more accustomed to other modes of communication such as SMS messaging (Moller et al. 2012; Ekegren et al. 2014).

SMS-messaging has previously been demonstrated as a promising tool for injury occurrence measurement in handball (Moller et al. 2012), soccer (Clausen et al. 2014; Nilstad et al. 2014) and community sport (Ekegren et al. 2014; Ekegren et al. 2015), and initial evidence of validity has been demonstrated in senior sport (Nilstad et al. 2014; Ekegren et al. 2015). However, a drawback to the previous use of SMS messaging for injury surveillance in team sports has been the general inability to seek further clarification about the brief text responses. Moreover, no prior studies have attempted to measure the consequences of injury beyond time lost from sport from the players' perspective using SMS messaging.

Therefore, we developed the SMS, Phone, and medical staff Examination (SPEx) sports injury surveillance system to address the limitations of previous approaches by integrating a

text-based approach to capturing all forms of injury, with telephone follow-up and player measures of injury consequences. The aims of this study were to evaluate the proportion of injuries and the agreement between sports exposures reported by the SMS messaging and follow-up telephone part of SPEx when compared to measures obtained by trained on-field observers and medical staff.

## MATERIALS AND METHOD

### Study design and participants

This was a prospective methodological cohort study including elite adolescent handball players in the "under 16" (U-16) or "under 18" (U-18) divisions of the Danish handball league. We enrolled a convenience sample of players from a sports college specializing in handball. The college was selected, as there were full-time sports physiotherapists coordinating medical care. First, we invited the college, their coaches and physiotherapists to participate through e-mail. After reviewing the study protocols with the coaches and physiotherapists, we invited all eligible players to participate in the study. Weekly reporting of handball exposure time and handball related injuries were measured from the players over 12 consecutive weeks (from December 30$^{th}$, 2012 to March 24$^{th}$, 2013) by both the SPEx system as well as by trained on-field observers and medical staff (comparison method) concurrently. No incentives were offered for participation. According to Danish law, The Ethics Committee of Central Denmark Region deemed the study to be exempt from full ethical review (167/2012) due to the study design (methodological observational study). The Danish Data Protection Agency (J. nr. 2012 - 41 -1042) approved the study. All participants provided their signed informed consent before study enrolment.

**Outcomes**

An injury was defined as any handball related injury that resulted in the following: the inability to complete a full training or match session, missing a subsequent session, or medical attention (Emery et al. 2005). Match and training exposure was defined according to the F-MARC consensus statement previous used in handball (Fuller et al. 2006; Moller et al. 2012).

**The SPEx sports injury surveillance system**

The SPEx system obtains information from players through three methods: SMS messaging, telephone interviews, and physical examination by medical personnel.

Every Sunday, participants received a series of SMS messages in two parts (Figure 1). The messages included questions from the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire (Clarsen et al. 2013). Non-responders received a reminder SMS the following Tuesday and Wednesday.

Part 1 comprised three questions about injury occurrence, training exposure, and match exposure (Figure 1, questions 1, 6, and 7). The first of the four OSTRC questions (Clarsen et al. 2013) (Figure 1, question 1) was used to identify an injury. Players' self-reporting injuries in question 1 were sent additional messages. Part 2 involved further questions (Figure 1, questions 2-5) to classify the injury as new or existing and document its consequences on training, performance, and pain.

To decrease question volume and improve responding, our delivery of the OSTRC questions differed from the original questionnaire (Clarsen et al. 2013) in three ways:

1. Questions 3, 4, and 5 (Figure 1) were only sent to injured players and not to all participants;

2. The players answered questions 1, 3, 4, and 5 (Figure 1) concerning all physical problems and not specific body regions;
3. For physical problems not leading to time-loss, we distinguished between those with and without medical attention by adding an extra option to question 1 (Figure 1): "3. Full participation, but with physical problems and contact to medical personnel", and adding "(no contact to medical personnel)" to option 2.

Following the 2006 injury consensus statement (Fuller et al. 2006) the SMS questions were designed to comprise all physical problems irrespective of the need for time-loss or medical attention. We decided to use the phrase “physical problem” instead of “physical complaints” suggested by Fuller et al.(Fuller et al. 2006). This was done to be consistent with the OSTRC-questionnaire (Clarsen et al. 2013) and because some players had difficulty understanding the interpretation of ‘complaint’ in Danish translation. Before enrolment, participants received oral and written information detailing the definition of a “physical problem” (pain, discomfort, soreness, stiffness).

As a part of the SPEx method, players injured at study start and players reporting a new injury during the study were contacted within one week by trained final year physiotherapy students who obtained additional injury details through a 5-10 minute standardized telephone interview addressing injury mechanisms, injury location and type as described previously (Moller et al. 2012). If multiple injuries were identified in the follow-up telephone interview, players were asked to identify their worst injury, and then continue to report this injury and its consequences the following weeks.

The last part of the SPEx method is the physical medical examination of reported injuries. This part was not applied in the present study

**Comparison method**

Our comparison method was the injury surveillance system described by Emery et al. (2005). Trained team designates (volunteer coaches from each of the included college teams) attended each training and match session, and collected information on individual sport exposure hours and injury occurrence. An injury report form was used to document any handball related injury. The team designates initiated the injury report form at the time of injury, and a trained physiotherapist completed the form. Unlike Emery et al. (2005), we included medical attention injuries not resulting in time-loss form sport when players sought medical attention from the physiotherapists between training/match sessions. Players were referred to a sports medicine physician, at the discretion of the physiotherapist, which differs from the original approach by Emery et al. (2005), where all players with time-loss injuries were referred to a physician.

The team designates recorded handball exposure on a weekly exposure sheet. Exposures were categorized as 1) Full participation (player participating 75% of the time or more), 2) partial participation (player participating, but less than 75%), or 3) no participation. All injury report forms and weekly exposure sheets were administered to the principal investigator every week.

**Statistical analysis**

All statistical analyses were conducted in Stata version 14.1 software (StataCorp, College Station, TX, USA). To evaluate the proportion of injuries reported by both methods, we calculated the percentage of injury reports reported by SPEx only, by the comparison method only, and by both (Ekegren et al, 2015). In the comparison of injury reports, we used any injury registration irrespective if it was a new injury or an injury previously reported during the study period. Physical problems recorded by SPEx that did not result in the inability to

complete a full session, missing a subsequent session or medical attention were not included in the comparison.

We also registered how many weeks a player in total was affected by injury and divided this into 4 main categories: 1: No injury; 2: Mildly affected (≤1 week); 3: Moderately affected (>1 and ≤ 4 weeks); and 4: Severely affected (>4 weeks) (Fuller et al. 2006). This was compared between the two methods by a 4x4 table and with Cohen's linear weighted kappa statistics. For SPEx, a missing answer in this analysis was handled in the following way: if the player reported an injury in both the previous and the following week, we considered the player to be injured. Otherwise, we considered the player to not be injured.

Furthermore, we compared exposure times reported by SPEx and the comparison method by estimating 95% limits of agreement (Bland & Altman 2003). For SPEx missing answers were excluded. In the comparison method, if a player had participated only partially (more than 0%, but less than 75%), the comparison exposure time was estimated as 0.5 times the total exposure time for that training or match (Emery et al. 2005).

## RESULTS

Forty-six players from four teams were invited to participate. Of these, one team of 14 players elected not to participate, 6 players attended the college morning training but not the club training, and 2 players did not answer any of the SMS-questions during the study period. Thus, data from 24/46 (52%) players were included in the analysis. The demographics of the study population are described in Table 1.

The proportion of players' weekly responses to the SMS messages (after reminders) in SPEx ranged from 96% at the beginning of the study to 75% after 12 weeks. When players responded more than 1 to question 1 (Participation in training and competition, Figure 1), the

response proportion to question 2 (New or Same injury, Figure 1) was 99%. The total response proportions to questions 6 and 7 were 97%. We obtained additional injury details for ninety-two percent of new injuries and injuries at baseline in the subsequent telephone interview. The assigned team designates in the comparison method provided complete data for each week during the study period.

**Comparison of handball exposure, injury occurrence, and consequences**

We obtained a total of 86 registrations of injury occurrences out of 288 observations by the SPEx and comparison methods. The two methods agreed upon 41 injury registrations and 157 non-injury registrations. Thirty-five injury registrations (41%) were captured by SPEx only, 10 injury registrations (12%) by the comparison method only (Table 2).

The vast majority (24) of the 35 injury registrations missed by the comparison method were categorized as medical attention injuries not leading to time loss by SPEx (response 3 to question 1). The comparison method had classified three of the remaining missing registration as non-injuries and "absence for other reason".

Of the 10 injury registrations only captured by comparison method, 3 were due to non-response in SPEx, 1 injury was classified as a physical problem not leading to time-loss or medical attention and was not included in this analyses, and 6 players reported no injury in SPEx.

Figure 2 shows the registrations of injury status for each player reported by both methods during the 12-week of follow-up. As illustrated in the Figure, 34/48 (71%) of the missing values in SPEx were derived from four players (ID 6, 11, 14, and 16). Only one player had complete identical observations by both methods (ID 23).

The vast majority of the injury registrations identified by both methods were “the same injury as last week” (SPEx: 85%, Comparison: 78%). Three new injuries were recorded by the comparison method only, while 5 injuries were recorded by SPEx only. Seven new injuries were recorded by both methods; 3 of these were, however, registered by SPEx with a delay of one week (Figure 2, ID 5 and 8) or in the previous week (Figure 2, ID 11).
The SPEx method recorded 12 "physical problems" that did not result in time-loss or medical attention and therefore did not counted as reportable injuries in the comparison analysis.

SPEx had 48 missing answers, of these, 2 missing values were imputed as injury using the analytical approach previously described. The differences between the numbers of weeks players were affected by injuries divided into the four categories measured by SPEx and by the comparison methods are illustrated in Table 3. The percentage of agreement was estimated to 83.33% with a weighted kappa of 0.61 (95% CI 0.49 to 0.74).

The exposure time reported by the SPEx and comparison methods is presented in Table 4. Weekly exposure time differences (95% limits of agreement) between SPEx and the comparison method ranged from -5.2 to 6.5 hours (training) and -1.6 to 1.0 hours (match) with systematic differences being 0.7 hours (95% CI 0.3 to 0.10) and -0.3 (95% CI -0.4 to -0.2), respectively.

## DISCUSSION

The SPEx sports injury surveillance method identified 88% of all reported injury registrations, and 33% more injuries compared to the comparison method. This supports the ability of the SPEx system to identify medical and time-loss injuries.

Several factors need to be considered when interpreting these results. According to the comparison method (Figure 2) 6 players, though responding to SMS messages, did not report their injuries. The false negative answers may be because of the burden of extra SMS questions and follow up by phone, which also has been argued as a possible reason for the injury decline in the study by Ekegren et al. (2014).

SPEx found more injury registrations than the comparison method. In particular, two-thirds (24/35) of the injury registrations missed by the comparison method were recorded as medical attention injuries by SPEx. However, only 5 were new injuries or injuries experienced prior to the study, and therefore further followed up in the telephone interview. All 5 players sought medical assistance outside of the medical personnel affiliated with the handball team, thus supporting the hypothesis that sole reliance on field observation may underestimate injury occurrence and consequences, which is also argued by (Nilstad et al. 2014).

The remaining 19 injury registrations were recorded as "the same injury" as last week and therefore not followed up by telephone interview. Unfortunately, the physiotherapists participating in the comparison method only recorded new injuries, and it is, therefore, unknown if these registrations from the players represent actual injury registrations or false positive responses. However, our results are in line with previous studies which have found that using SMS messages for injury registration captures approximately 50% more injuries than traditional medical staff-based (Nilstad et al. 2014) or sport trainer-based observations (Ekegren et al. 2015). Unlike these studies, we did not restrict our analyses to new injuries but considered all injuries whether or not they had been previously reported. As illustrated in Figure 2, some players reported the same injury as last week without actually having had an injury in the previous week. This emphasizes that all "same injury" self-reports in SPEx should also be followed up carefully in future studies.

Another source of discordance impacting the number of injury registrations from SPEx was that three time-loss 'injuries' identified by SPEx were classified as non-injuries and "absence for other reason" by the comparison method. This highlights the potential to improve the SPEx method by including an option for players to indicate that their absence was due to other reasons than a sport-related injury (e.g., illness or holiday).

There was moderate between-method agreement on injury consequences (weeks affected by injury). SPEx tended to classify injury consequences as more severe than the comparison method, but these results may have been influenced by the fact that we did not contact players reporting "the same injury like last week". These results may also be influenced by the missing answers in SPEx. Missing data are frequently encountered in injury surveillance, especially when tracking large cohorts of athletes. Thus, considerations for dealing with missing data are relevant for all methods of injury surveillance. As opposed to SPEx, the assigned team designates in the comparison method provided complete registrations. Using our imputation of missing values approach, two of 48 missing values were imputed as injuries, and it is unlikely that this has influenced the study results (Table 2).

SPEx also identified 12 "physical problems" registrations that did not lead to time-loss or medical attention. This is consistent with previous research reporting an underestimation of injury burden when restricting injury definitions to only events resulting in time-loss or the need for medical attention (Clarsen et al. 2013).

Considering exposure to match-play and training, SPEx recorded more training hours, but fewer match hours than the comparison method. In particular, we believe that the SPEx method provides a better estimate of match exposure time because a player with, e.g., 5 minutes match exposure is expected to report this, while the comparison method will categorize the player as having participated partly, thus being considered having played 30 minutes (50% of 1 hour match time). These measurement differences have potential to result

in important discrepancies in exposure and injury outcomes and emphasize the importance of valid measurement to avoid discrepancies of injury incidences between studies, and may be the reason why Møller et al. (2012) found a higher match incidence using SMS messages compared to previous studies.

These results should be considered in light of the study's strengths and limitations. The primary study strengths include the 12-week longitudinal design and side-by-side comparisons of a highly standardized measurement to an established, validated injury surveillance system. This was the first study to include player measures of injury consequences within a system comprising SMS messaging and telephone follow-up. We observed a decline in response rates over time, which may indicate that some participants were experiencing 'response fatigue'. Nevertheless, this did not appear to have a substantial impact on the agreement estimates.

Study limitations include the relatively small sample, and that 48% (22 players) either chose not to participate or were excluded in the study. Investigating a larger cohort of athletes would allow us to explore a wider spectrum of injuries with greater precision. This affects the external validity of our results, which may not generalize other populations. In fact, the response proportions to the SMS questions in this study is lower than previous studies in larger cohorts (Moller et al. 2012; Clausen et al. 2014; Ekegren et al. 2014; Nilstad et al. 2014; Ekegren et al. 2015), and it is possible that the results would be different if it had been performed in another college. Finally, the study sample comprised adolescent elite handball athletes, who are expected to have a high compliance, and these results, may not generalize to other sports or non-elite populations who might be less motivated to participate in studies. However, when used in the general population, participation proportions have been high (Jespersen et al. 2015), indicating the potential for strong participation outside of elite sport.

## PERSPECTIVES

This study is the first to investigate the concurrent validity of SMS messaging in youth sport. Our results support the ability of the SPEx system to identify medical and time-loss injuries. Using

the SMS and phone parts of SPEx appears to be superior and is likely to be a less costly approach to measuring sports injuries and exposures compared to the use of side line observers and medical staff.

The high response rates to all seven questions indicate that it is possible to incorporate the OSTRC questions to measure injury consequences via SMS messaging as opposed to of e-mail – an approach that may be particularly attractive to youth athletes. The SPEx system facilitates the early identification of injuries as well as tracking of symptoms and recurrent events. However, the feasibility of the complete SPEx system, which also includes the validation of the reported injuries by medical staff, needs to be investigated in a large cohort over the course of at least one season.

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## TABLES

**Table 1. Demographics of participants.**

| | (n=24) |
|---|---|
| **Sex** | |
| Boys n (%) | 10 (42) |
| Girls n (%) | 14 (58) |
| **Age group** | |
| U-16 n (%) | 6 (25) |
| U-18 n (%) | 18 (75) |
| **Mean age (sd)** | 17.0 (0.9) |
| **Player position** | |
| Back players n (%) | 9 (38) |
| Wing players n (%) | 9 (38) |
| Line players n (%) | 4 (17) |
| Goal keepers n (%) | 2 (8) |
| **Mean years handball experience (sd)** | 9.7 (3.0) |
| **Mean hours weekly handball training (sd)** | 9.6 (3.2) |

**Table 2. Injury registrations by SPEx and comparison (Observer+medical staff) methods.**

| | **Observer + medical staff** | | |
|---|---|---|---|
| **SPEx** | Injury | No injury | Total |
| Injury | 41 | 35 | 76 |
| No injury | 7 | 157 | 210 |
| Unknown injury status due to missing responses | 3 | 45 | |
| Total | 51 | 237 | 288 |

**Table 3. Injury consequenses by the SPEx and comparison (Observer+medical staff method).**

| | Observer + medical staff | | | | |
|---|---|---|---|---|---|
| **SPEx** | None (0 weeks) | Mild (1 week) | Moderate (2-4 weeks) | Severe (>4 weeks) | Total |
| None (0 weeks) | 7 | 1 | 0 | 0 | 8 |
| Mild (1 week) | 2 | 0 | 1 | 0 | 3 |
| Moderate (2-4 weeks) | 1 | 2 | 4 | 0 | 7 |
| Severe (>4 weeks) | 0 | 1 | 2 | 3 | 6 |
| Total | 10 | 4 | 7 | 3 | 24 |

**Table 4. Exposure time by the SPEx and comparison (Observer+medical staff) methods**

| | **SPEx** | | **Observer + medical staff** | | **Bias (95% CI)** | **Limits of agreement (95%)** |
|---|---|---|---|---|---|---|
| | All players | Mean (95% CI) | All players | Mean (95% CI) | | |
| Training* (hours) | 1315 | 5.6 (5.2 to 6.0) | 1269 | 4.5 (4.1 to 4.8) | 1.1 (0.8 to 1.5) | -4.3 to 6.6 |
| Match † (hours) | 119 | 0.5 (0.4 to 0.6) | 216 | 0.8 (0.7 to 0.9) | -0.3 (-0.3 to -0.2) | -1.5 to 1.0 |
| Total (hours) | 1434 | 6.1 (5.7 to 6.5) | 1484 | 5.2 (4.8 to 5.6) | 0.9 (0.5 to 1.3) | -4.7 to 6.5 |

***** Based on 235 observations due to 53 missing responses in SPEx
† Based on 236 observations due to 52 missing responses in SPEx

## FIGURES

**Please also find the figures uploaded separately**

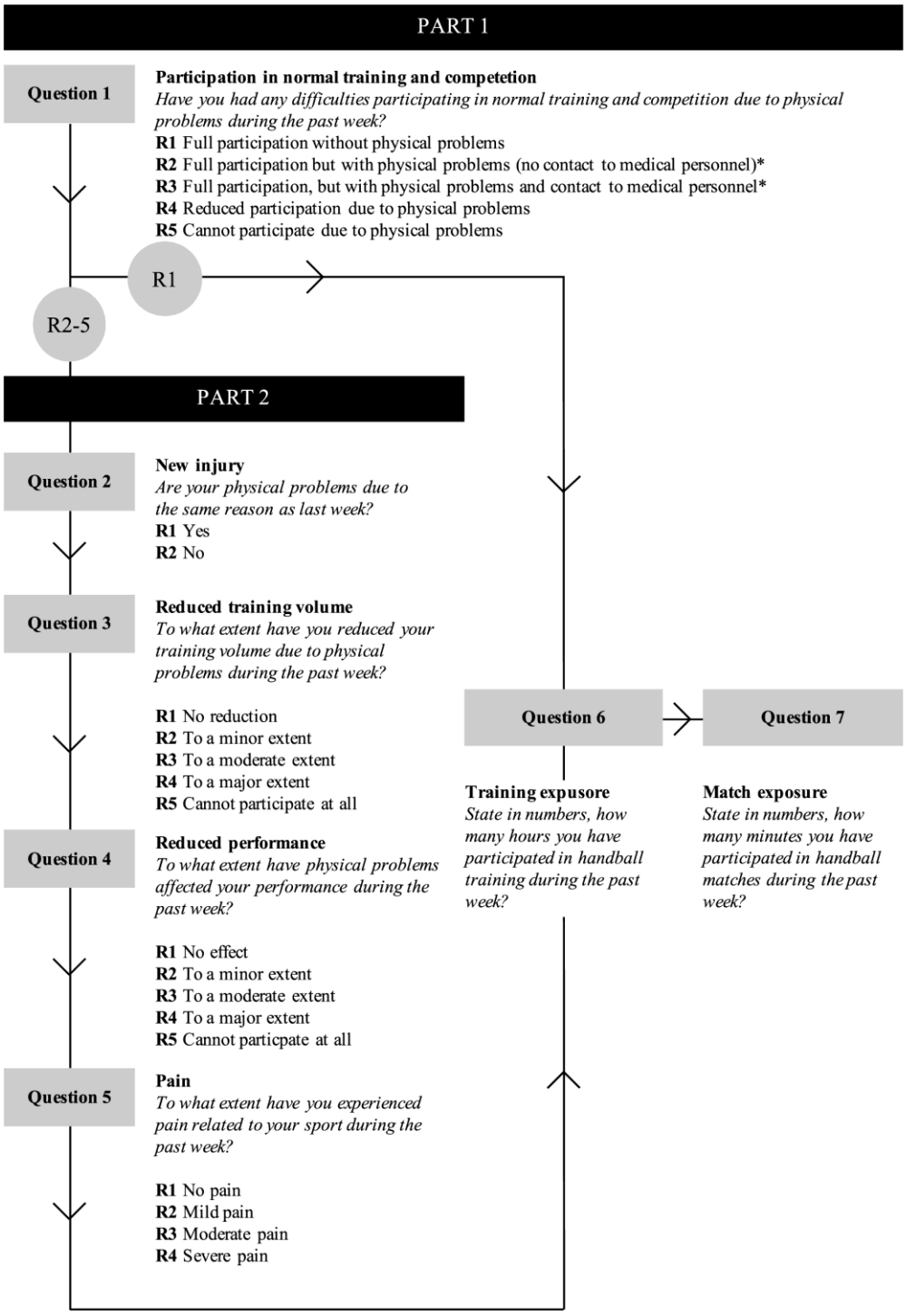


**Figure 1. SMS message flow in SPEx**
*****Response modified compared to the original OSTRC overuse questionnaire (Clarsen et al. 2013).

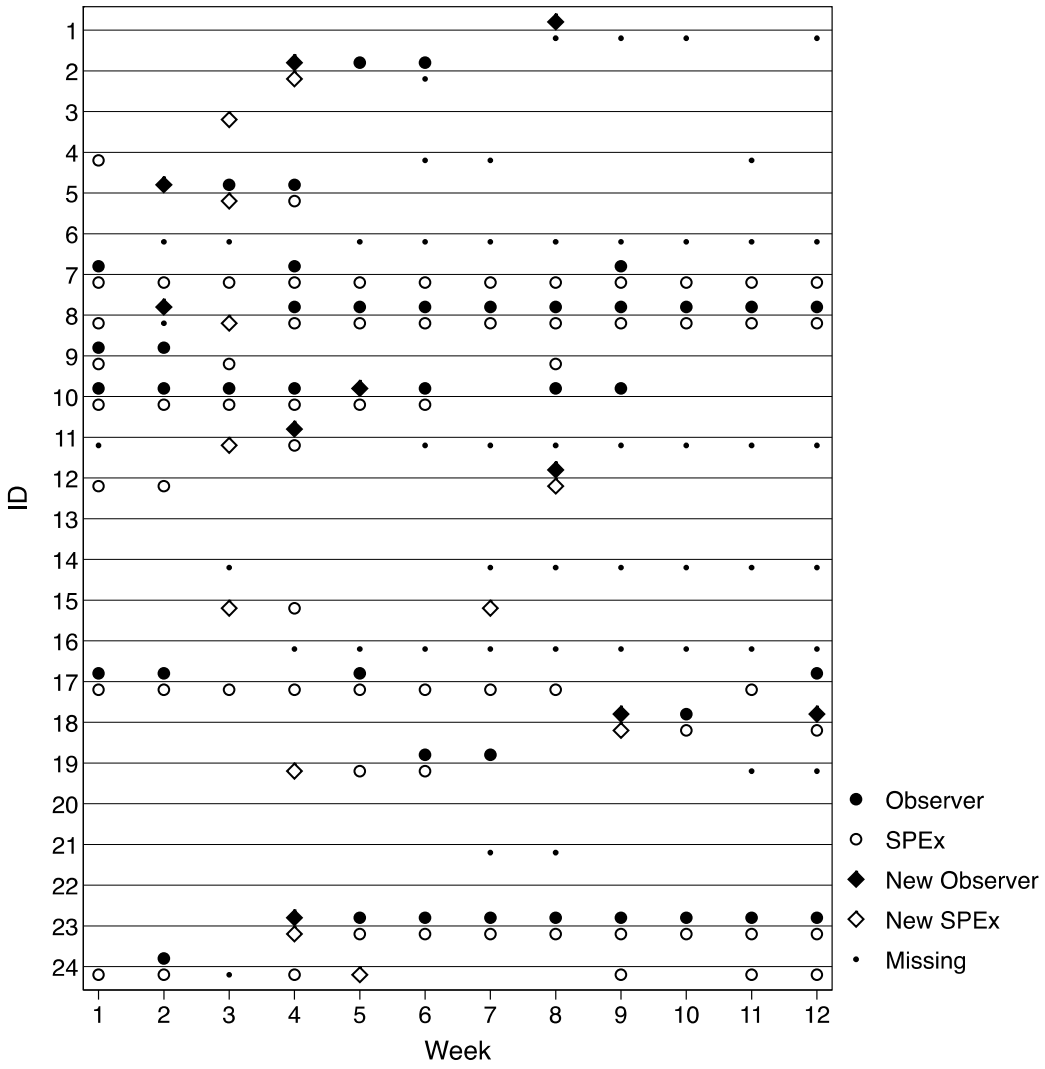


**Figure 2. Injury registrations by the SPEx and reference (Observer) methods during the 12-week study period.**

● Previous reported injury or injury before study start by reference (Observer) method ○ Previous reported injury or injury before study start by SPEx ◆ New injury by reference (Observer) method ◇ New injury by SPEx ・Missing