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TITLE PAGE

The SMS, Phone and medical Examination sports injury surveillance (SPEx) system is a feasible and valid approach to measuring handball exposure, injury occurrence and consequences in elite youth sport

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ABSTRACT

Current methods of sports injury surveillance are limited by lack of medical validation of self-reported injuries, and/or incomplete information about injury consequences beyond time-loss from sport. The aims of this study were to 1) evaluate the feasibility of the SMS, Phone and medical Examination injury surveillance (SPEx) system 2) to evaluate the proportion of injuries and injury consequences reported by SPEx when compared to outcomes from a modified version of the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire. We followed 679 elite adolescent handball players over 31 weeks using the SPEx system. During the last 7 weeks, we also implemented a modified OSTRC questionnaire in a subgroup of 271 players via telephone interviews. The weekly response proportions to the primary SPEx questions ranged from 85% to 96% (mean 92%). SMS responses were received from 79% of the participants within 1 day. 95% of reported injuries were classified through the telephone interview within a week, and 67% were diagnosed by medical personnel. Comparisons between reported injuries from SPEx and OSTRC demonstrated fair [κ=39.5% (25.1% to 54.0%)] to substantial [PABAK=66.8% (95% CI 58.0% to 75.6%)] agreement. The average injury severity score difference between SPEx and the OSTRC approach was -0.2 (95% CI -3.69 to 3.29) out of possible 100 with 95% limits of agreement from (-14.81 to 14.41).

These results support the feasibility and validity of the SPEx injury surveillance system in elite youth sport. Future studies should evaluate the external validity of SPEx system in different cohorts of athletes.

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

INTRODUCTION

The benefits of engaging in physical activity in youth are well documented (1, 2), and organized sport participation increases opportunities for health-related physical activity and may decrease cardiovascular risk (3, 4). However, sport participation can also have negative consequences due to injuries. Injury is one of the main reasons for individuals to cease participation in sport and is a source of disability in the short and long term (5). Thus, injury prevention in youth sports seems to be important to reduce morbidity and maximize opportunities for health-related physical activity across the lifespan. However, effective prevention efforts depend on high-quality information on the occurrence and consequences of injury (6).

Traditionally, sports injury surveillance research has focused on the identification and prevention of serious time-loss traumatic injuries (7). Consequently, little is known about other injury types, (e.g., overuse injuries not resulting in time loss), as well as the consequences (e.g., change in function and performance) beyond time lost from sport experienced by injured athletes. One reason for this knowledge gap has been the lack of surveillance methods to identify the full spectrum of sport-related injuries.

Recent technological and methodological advances have provided new opportunities to measure sport-related injury. The Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire was developed to improve the identification of sport-related injuries and their consequences, e.g., change in function and performance. This method involves a weekly e-mail distribution of four primary questions to record overuse injuries (7). This represents an important advance in injury epidemiology as it identifies many injuries missed with traditional approaches as well as their consequences (7). However, the large volume of questions needed to address multiple injuries can be problematic (7, 8) as can the delivery of questions via e-mail in young athletes who may be more accustomed to other modes of communication such as SMS messaging (9, 10).

Another drawback to the OSTRC Overuse Injury Questionnaire is the lack of validation of the self-reported injuries by medical personnel, which is a possible threat to the validity of the data.

We developed the SMS, Phone, and medical staff Examination (SPEx) sports injury surveillance system to address these limitations by integrating a SMS messaging and clinician involvement to capture all types of injury and injury consequences. We, thus, modified the questions in the OSTRC Overuse Injury Questionnaire so that it can be used to record the consequences of all injuries and not only for overuse injuries in a specific body region. Our previous study demonstrated the ability of SPEx to accurately measure sport exposures, time-loss and medical injuries when compared to injury surveillance performed by trained observers (11). The SPEx system identified 88% of all reported injury registrations, and 33% more injuries compared to the trained observers. However, the ability of the SPEx system to measure injuries irrespective of time-loss and medical attention, and their consequences, as well as the feasibility when applied in larger cohorts, remains unknown. Therefore, the main objectives of this study were to assess the feasibility of measuring sport exposures and injuries via the SPEx system in a large cohort of adolescent athletes in terms of response proportions and response time. In SPEx, the four modified OSTRC Overuse Injury questions are sent only to injured players by SMS. Therefore, we aimed to examine the agreement between measures of injury occurrence and injury consequences obtained by the SPEx system and by an approach where the modified OSTRC questions are delivered to all players via telephone interview.

METHODS

Design

We followed adolescent handball players for 31 weeks from October 13th 2013 until May 11th 2014. Sports injuries were recorded weekly using the SPEx injury surveillance system. During the last 7

96 weeks, we also measured injury occurrences and injury consequences using the modified version of
97 the OSTRC Overuse Injury questions delivered via telephone interviews (7). The 7-week period
98 was determined based on our sample size calculation. This study also involved a baseline testing
99 procedure, but this was not included in the present paper.

100 **Injury definition**

101 In accordance with the 2006 injury consensus statement (12), injuries were defined as any sport-
102 related physical problem irrespective of the need for time-loss or medical attention. We decided to
103 use the phrase "physical problem" instead of "physical complaints" used by Fuller et al. 2006. This
104 was done to maintain consistency with the OSTRC Overuse Injury Questionnaire (7) and because
105 some players had difficulty understanding the interpretation of "complaint" in Danish translation.
106 Prior to enrolment, participants received oral and written information explaining the definition of a
107 "physical problem" (pain, discomfort, soreness, stiffness). This was also included in the main injury
108 question in our series of SMS messages as described later.

109 **The SPEx sports injury surveillance system**

110 Our first step in the development of the SPEx system has been described in detail elsewhere (11).
111 Briefly, SPEx obtains weekly information from players in three ways: SMS messaging, telephone
112 interviews, and physical examinations performed by medical personnel. The SMS messages
113 comprise seven questions delivered in two parts (Figure 1). Part one includes three questions to
114 identify training and match exposures and injury occurrence. Part two is based on the OSTRC
115 Overuse Injury Questionnaire (7) and consists of four additional questions sent to injured athletes to
116 record the consequences of injuries identified in part one. These questions were translated from the
117 original Norwegian version into Danish by the principal investigator (MM). Then the translated
118 version was reviewed by the Norwegian author (GM to check for inconsistencies in the translation
119 process. An injury consequence score was calculated from participants' answers to part 2 questions

120 (questions 4-7) (7, 13). Injury consequence scores ranged from 0 to 100, with higher scores
121 representing greater consequences resulting from injury. We classified substantial injuries as
122 injuries leading to moderate or severe reductions in training volume or performance, or total
123 inability to participate (players who selected option 3,4 or 5 in either question 5 or 6) (7).
124
125 Based on player feedback and the results from our preliminary study (11), we made three changes
126 in our SPEx questions compared to the original OSTRC Overuse Injury Questionnaire:
127 1. Part two questions (Figure 1, questions 4-7) were only sent to injured players.
128 2. To reduce the volume of questions, the players answered the part 2 questions (Figure 1,
129 questions 4-7) with reference to all physical problems and not to specific body regions.
130 3. We added an additional response option (response 5) to Question 7: *"Cannot participate at*
131 *all"*. This outcome was scored the same as "Severe pain" (response 4) when calculating the
132 injury consequence score.
133
134 [Please place Figure 1 near here]
135
136 Players who reported an existing injury at baseline, or a new injury during the course of the study,
137 underwent a standardized 5-10-minute telephone interview within one week. Four trained
138 physiotherapists performed the interviews every Monday after the initial SMS, and every
139 Wednesday and Thursday after the reminder-SMS. The interview identified the mechanism(s),
140 location(s) and type(s) of injury as described previously (10). When multiple injuries were reported,
141 players were asked to identify their worst injury, and then continue to reference this injury in
142 subsequent reporting.

143 Next, a trained physiotherapist conducted a 30-minute standardized physical examination on injured
144 players 1-2 weeks from the original report. Recurrent injuries in the study period were only
145 examined if the player felt it was necessary, or if the injury diagnosis was uncertain. Injury
146 diagnoses were documented with ICD-10 and Orchard codes (version 10.1). In total, six full-time
147 physiotherapists conducted the telephone interviews, and performed physical examinations for 6
148 clubs. For the remaining 23 clubs, local physiotherapists were recruited. All physiotherapists
149 participated in a one-day training session to ensure standardization of the study procedures. The
150 musculoskeletal examination procedures were primarily based on recommendations from and
151 Brukner & Khan (14). When players were referred to a hospital for assessment of their sport-related
152 injury, we obtained the relevant medical records to avoid repetitive physical examinations.

153 **Comparison method**

154 During the last seven weeks of the study, we also recorded injuries (irrespective if it was a new or
155 existing injury) using the four modified OSTRC Overuse Injury Questionnaire part 2 questions
156 (Figure 1). Each week, a random sample of 40 players who were not previously selected, were
157 asked the four questions through a standardized telephone interview. The interviews were
158 conducted by one or two physiotherapists who were blinded to the players' SPEx outcomes. During
159 the interview, the four modified OSTRC questions were presented. When an injury was identified,
160 the interviewer asked whether the player had reported that injury via SMS. Reasons for reporting
161 discrepancies were explored in one follow-up question. An injury consequence score was calculated
162 from participant's answers to these questions (questions 4-7) as described earlier (7, 13).

163 **Participants**

164 We recruited elite handball players from all First Division U-18 (under 18 years of age) teams in
165 Denmark, and from First Division U-16 teams from clubs that also had a participating U-18 team.
166 The recruitment period was from August to October 2013. First, coaches were contacted about

participation. If they accepted, the principal investigator provided players and parents with oral and written information at a training session prior to study enrollment. New players were allowed to enter the study at midseason (December 2013 to January 2014).

No incentives were offered for participation, and all participants gave their informed consent prior to study enrolment. Permission for the study was granted by the Danish Data Protection Agency (J.nr. 2013-41-2137) and The Central Denmark Region Committees on Health Research Ethics (request 89/2013).

Statistical analysis

All statistical analyses were conducted in Stata version 14.1 software (StataCorp, College Station, TX, USA). The feasibility of the SPEx system was evaluated in terms of response rates, response times to SMS messages, number of injuries reported by SMS that were classified by follow-up telephone interviews, time to classification of injuries, and number of classified injuries that were diagnosed by physical examination. We calculated the weekly injury prevalence by dividing the number of players who reported an injury by the number of SMS respondents the given week (Clarsen et al 2014).

When comparing injury occurrence between SPEx and the comparison method, we used any injury registration irrespective if it was new or pre-existing. First, we evaluated the proportion of injuries reported by both methods, and calculated the percentage of injury reports reported by SPEx only, by the comparison method only, and by both (15).

Agreement for dichotomous outcomes (injury occurrence) was estimated using Cohen's linear weighted kappa statistics. Kappa values can be influenced by the prevalence of injuries and by systematic differences (bias) between the data sources (16, 17). We therefore also calculated the

190 indices of prevalence and bias, and prevalence-adjusted bias-adjusted kappa (PABAK) coefficients
191 to assist kappa interpretations.
192 Benchmarks suggested by Landis and Koch (18) were used to interpret kappa and PABAK
193 outcomes (>0.81, almost perfect; 0.61 to 0.80, substantial; 0.41 to 0.60, moderate; 0.21 to 0.40, fair;
194 0.00 to 0.20, slight; and <0.00, poor). When injury registrations were identified by both methods,
195 injury consequence scores were compared using Bland Altman bias and limits of agreement (19).
196 For feasibility and kappa analyses, missing answers to question 3 (Figure 1) in SPEx were handled
197 in the following way: If the player reported an injury in both the previous and subsequent weeks,
198 we considered the player to be injured. Otherwise, the player was classified as not injured (11). For
199 the comparison method, it was not possible to impute missing values as participants were randomly
200 sampled for only one measurement point. Therefore, all missing values in this approach were coded
201 as no injury.
202 The number of participants included in the comparison analysis was based on our a priori thoughts
203 of estimating the sensitivity of injury outcomes obtained by SPEx system when compared to the
204 modified OSTRC method. Using this approach, the number of measurements needed to estimate a
205 sensitivity of 80% with a corresponding 95% confidence interval of ±0.15 was calculated with the
206 following formula: N = 1.96^2 / (b/2)^2 * sens * (1 - sens) / p. Where sens is sensitivity and p are
207 the prevalence of injuries according to the gold standard, and the width of the 95% CI is b.
208 The prevalence of physical problems measured with the modified OSTRC (22%) was expected to
209 be 10% higher than that obtained by SPEx (20%). Based on these assumptions, we therefore
210 required 280 independent measurements to achieve sufficient precision. We divided this on a 7-
211 week period, as we were capable of calling 40 players each week.
212

RESULTS

Study population

Participant flow is presented in Figure 2, and demographics of the study population are described in Table 1. In total, 68 U-18 teams and 31 U-16 teams were invited to participate. Fifty-four percent of the invited teams (15 U-16 teams and 37 U-18 teams), comprising 686 players (44% female), were enrolled in the study. Of the 46 teams who declined to participate, 32 teams did not respond to the invitation, 11 teams did not have time to be tested in the given time-period, and 3 teams were not interested in participation. Seven players (1.0%) were excluded from the analysis as they failed to respond to any SMS messages. Data from 36 players (5.2%) were censored when they reported that they would cease to respond to messages. Of these, eleven players stopped playing handball, 6 withdrew from the league, 4 expressed a lack of interest in the study, 3 experienced a season ending injury, 2 changed to another team that was not participating in the study, and 10 withdrew for unknown reasons.

From this sample of 679 players, 280 players were randomly selected for the method comparison analysis. Data from 9 players (1.1%) were excluded from the comparison analysis as they were among the participants who were lost to follow up or the participants who were censored.

[Please place Figure 2 near here]

[Please place Table 1 near here]

Feasibility of SPEx

The weekly response proportions to question 1 ranged from 97% at the beginning of the study to 88% at the end of the 31-week study period. The weekly response proportions to all part 1 questions (questions 1-3, Figure 1) ranged from 85% to 96% (mean 92%). Response proportions to part 2 questions (questions 4-7, Figure 1) ranged from 98% to 100% per week. Fifty-three percent of

237 players reported on all part 1 questions during all 31 weeks of the study. Eighty-five percent of
238 players provided part 1 answers during more than 80% of the study period, with 95% of all players
239 providing part 1 answers during more than 50% of the study period. Ninety-three percent of the
240 injured players provided complete answers to the 7 weekly SMS questions during the 31-week
241 study period.
242 Among participants who replied to part 1 questions, 79% responded on the day the SMS messages
243 were sent, 87% the day after, 95% on the second day (after first reminder), and 99% by the day
244 three (after the second reminder). Of the injured players, 72% had responded to all seven questions
245 the same day, 82% the day after, 92% the second day, 97% the third day, and 99% after four days.

246 **Injuries reported by SPEx**

247 Of 744 new and recurrent injuries reported via SMS, 709 injuries (95%) were evaluated via
248 telephone interviews; of these, 84% were evaluated the day after the SMS response, and 95% within
249 one week. Sixty-six percent of players were successfully contacted on the first phone call attempt
250 and 95% after 3 phone calls. Following telephone interview, 77 injuries (11%) were classified as
251 trivial, thus negating the need for physical examination. Of the remaining 667 injuries, 447 (67%)
252 were examined and diagnosed by a study physiotherapist (415 injuries) or by hospitals (32 injuries).
253
254 Figure 3 shows the prevalence of injuries and the response proportions to the part 1 questions for
255 each week. There was a decline in the injury prevalence and the response proportions during the
256 season.
257
258 [Please place Figure 3 near here]
259

Comparison of injuries and injury consequence score

During the last seven weeks of the study, we obtained a total of 67 registrations of injury occurrences out of 271 observations by the SPEx and comparison methods. The two methods agreed upon 21 injury registrations (32%) and 106 non-injury registrations (53%) (Table 2). Twenty-two injury registrations (33%) were captured by SPEx only, 24 injury registrations (36%) by the comparison method only (Table 2). The overall agreement, after we imputed missing values in SPEx, was estimated to 83.39%, the kappa value was estimated to 39.5 (95% CI 25.1 to 54.0) and the PABAK value was estimated to 66.8 (95% CI 58.0 to 75.6). The indices of prevalence and bias were estimated to -0.67 and 0.00, respectively.

SPEx had 43 (16%) missing answers, of these, 1 missing value was imputed as an injury. In the comparison method 165 (61%) responded to the phone calls (Table 2).

[Please place Table 2 near here]

All 22 injuries not recorded by the comparison method were due to missing responses to the phone calls. A total of 24 injuries were not recorded by SPEx. Of these, 9 were due to non-response to the SMS messages. Among the remaining 15 injuries, only one was classified as substantial. Nine injuries not identified in the present comparison week had already been identified by SPEx in previous weeks. SPEx identified the two substantial injuries, and two minor injuries the week before the comparison week. Further details of the 15 injuries not captured by SPEx are listed in Table 3.

[Please place Table 3 near here]

The mean injury consequence score reported by SPEx was 70.6 (95% CI 52.2 to 89.0) and by the comparison method it was 70.4 (95% CI 53.2 to 87.7) There was no evidence of a systematic difference in injury consequence scores between the two methods (-0.2; 95% CI -3.7 to 3.3), and the limits of agreement between SPEx and the comparison method were -14.8 and 14.4.

DISCUSSION

In this study, we aimed to explore the feasibility of the SPEx sports injury surveillance system, and its ability to capture injury reports not leading to time-loss or medical attention. The SPEx system was able to monitor a large cohort of athletes over the course of a 31-week season. Feasibility of this approach was demonstrated by the large proportion of responding players and short time of response to SMS messaging, telephone interviews, and attendance at physical exams. After correcting for the effects of prevalence and bias, comparisons of injury and injury consequence scores measured by the SPEx system and the modified OSTRC Overuse Injury Questionnaire approach using telephone interview demonstrated substantial levels of agreement. The difference found between kappa and PABAK coefficients was due to the large differences found in the prevalence of positive and negative determinations of injuries, which makes it impossible to get high Kappa values, thus a Kappa value should always be considered together with the prevalence of the cases studied (Byrt el al 1993).

There are several factors that need to be considered when interpreting the results. In our study, injured players had to answer seven SMS messages compared with one or three to four SMS messages in previous studies, who have reported similar response proportions (9, 10, 20, 21). The response proportion to the four extra questions for injured players ranged between 96-100%, indicating that the additional questions did not negatively impact the proportion of SMS responses.

306 The response proportion and the number of reported injuries decreased during the season. A similar
307 decline has been reported by Ekegren et al. (2014), who only used one SMS question and this may
308 be an indicator of response fatigue resulting from the duration of monitoring, irrespective of the
309 number of SMS questions. This decline was not observed in a large cohort of children during 2.5
310 years of weekly messaging, irrespective if the children were sport active or not, but in this study, it
311 was the parents who responded to the SMS messages and not the children (22). In the present study,
312 96% of new injuries were classified by telephone interviews, and 84% of these injuries were
313 classified within one day of initial reporting via SMS. This demonstrates the SPEx telephone
314 interviews to be acceptable to players and feasible when applied in a large cohort. This makes it
315 possible for the research or medical personnel to respond rapidly to injury reports from players, and
316 thereby minimizing the risk for recall bias, and facilitating referral to medical physical examination
317 when needed. To our knowledge, no other large-scale studies in adolescent team sports have
318 validated injury self-reports with physical examinations by medical personnel, which represents an
319 advantage compared to the original OSTRC Overuse Injury Questionnaire. Despite the moderate
320 proportion of injuries evaluated by physiotherapists, our study demonstrates that it is feasible.
321 However, our study suggests that this procedure can be improved by having two part-time
322 physiotherapists connected to each club, so that the procedure is less vulnerable for illness or
323 absence for other reasons. One of the main challenges of this part of the SPEx system was that the
324 injured players were already examined by the club's physiotherapists or at hospital, and therefore,
325 some of these players were not willing to undergo additional physical examination. We tried to
326 collect these data from the local hospitals, but this was a time-consuming process, and efforts
327 should be made to avoid this procedure as a part of the SPEx system in future studies.
328 In this study, it was not possible to provide a real-world evaluation of the financial costs of the
329 SPEx-system, and future studies should evaluate this aspect of the feasibility of the SPEx system.

However, the SMS messaging and telephone interview part can be completed for minimum expenses, and these parts alone provides more detailed injury information than what is obtained by for instance the OSTRC Overuse Injury Questionnaire.

We modified the OSTRC Overuse Injury Questionnaire for use in the SPEx injury surveillance system by recording all injuries, and not solely in predefined anatomical areas. Additionally, feedback from players in our previous study indicated a further need for modification (11). As a result, we modified the questionnaire to clarify situations in which players were unable to participate in training or match play for reasons other than injury. We also added the additional response option *"cannot participate at all"*, to the question: "*To what extent have you experienced pain related to your sport during the last week?" (*Figure 1, question 7). This change clarifies situations in which players whose participation is limited for reasons other than pain (e.g., concussion). Based on our results, we argue that these modifications should be considered when using the original OSTRC Overuse Injury Questionnaire. However, the most important difference between SPEx and the OSTRC Overuse Injury Questionnaire is that only injured players receive the 4 modified OSTRC Overuse questions, and as such the questions are only used as a method for recording consequences of injuries beyond time lost form sport. While we felt this to be a necessary modification due to limit response fatigue it is possible that this change restricted the reporting of some injuries when compared to if all players had received all questions. The OSTRC Overuse Injury Questionnaire is a valid measure of overuse injuries in athletes and an informative comparator for new approaches, but still, there is currently no criterion for measuring all sport-related injuries and illnesses irrespective of time lost from sport and medical attention. We, therefore, included the minor modifications to the OSTRC questions in our comparison method to avoid the duplication of questions for each body region. Additionally, to prevent response fatigue or misunderstandings to the SMS messages in SPEx, we chose to implement the OSTRC Overuse

354 Injury Questionnaire by telephone rather than e-mail as originally described (7). Therefore, it
355 should be emphasized that our results may not represent a direct comparison between the SPEx and
356 the OSTRC Overuse Injury Questionnaire. Nevertheless, we argue that the use of structured
357 telephone interviews is likely to yield better information than self-reported responses submitted by
358 email, and this may have improved the validity of our modified OSTRC questionnaire outcomes.
359 Sixty-one percent of participants responded to the phone calls, and this is similar to responses
360 reported in senior handball (63%) using the original OSTRC Overuse Injury Questionnaire (23). In
361 contrast, the mean proportion of response to part 1 SPEx messages was 92%, demonstrating that
362 SMS messaging may be preferable to other modes of communication such as email or telephone.
363 Importantly, if missing values were dropped from the analysis, the modified OSTRC telephone
364 interviews captured 15 (43%) more injuries when compared to SPEx. However, this is unlikely to
365 be an accurate reflection of the false negative rate (Table 3). SPEx had already captured 6 of 15
366 injuries in prior weeks (ID 1, ID 3, ID 4, ID 5, ID 6, ID 7). Furthermore, 14 of 15 injuries missed
367 by the SPEx method were classified as minor. Six of 15 players only reported mild pain in question
368 4 in the comparison method and did not consider this to be a physical problem. Consequently, the
369 false negative responses did not represent substantial injuries.
370 These results should be considered in light of the study's strengths and limitations. This study is the
371 first to record all injury occurrences, irrespective of time loss or medical attention, and to include
372 player measures of injury consequences assessed using a system comprising SMS messaging,
373 telephone interview and medical examination in a large cohort of elite athletes with weekly
374 reporting over an entire 31-week season. It is also the first study to evaluate two self-reports
375 methods that uses the same expanded injury definition irrespective of the need of medical attention
376 or time-loss from sport.

Limitations include the relatively short comparison period for the comparison analyses (seven weeks). The choice of period was based on our sample size calculation. This was based on our a priori thoughts of estimating the sensitivity of SPEx. However, to estimate the sensitivity requires that the reference method is guaranteed to have higher validity than the method we seek to validate. This was not the case in this study. Instead we have examined the agreements between the approaches, and it would have been informative to compare response proportions and injury occurrence over a longer duration. The comparison between the two methods was made at the end of a 31-week study period, where the lowest response and injury rates in SPEx were found (Figure2). It is possible that the results would have been different if we had done the comparison at the beginning of the study with higher response proportions. We imputed missing values in SPEx differently than in the comparison method, where all missing values were imputed as zero injuries. However, only one missing value was imputed as injury using that approach, and therefore it is unlikely that this has influenced the results.

Only 54% of eligible players were enrolled in the study, which limits the external validity of our results. It is likely, that many did not respond to our invitation because this study also included a testing procedure, which required one training session from each team. Furthermore, 11 teams were excluded as it was impossible to find the time for testing. Importantly, we had only 7 players who were excluded from follow-up and only 5% of all players were censored which emphasize the feasibility of the SPEx system.

Finally, the study sample comprised elite adolescent athletes, and these results may not generalize to other populations.

PERSPECTIVES

The accurate measurement of sport exposure time and injury occurrence is key to effective injury prevention and management (6). To achieve sustainable access to data, injury surveillance systems

must be convenient for the responders/players, and still provide valid information. We have, in this and in our previous study (11), demonstrated the SPEx system to be a feasible and valid option for researchers, coaches, teams, and others working with injury surveillance. This information is likely to provide medical and research staff with clinically relevant injury information, as well as the opportunity to monitor the training and match load, which is important to understand the causes and prevention of injury in sport (24). Future studies should evaluate the external validity of SPEx system in different cohorts of athletes.

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REFERENCES

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. The international journal of behavioral nutrition and physical activity. 2010;7:40.
2. Twisk JW, Kemper HC, van Mechelen W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. Int J Sports Med. 2002;23 Suppl 1:S8-14.
3. Hebert JJ, Klakk H, Moller NC, Grontved A, Andersen LB, Wedderkopp N. The Prospective Association of Organized Sports Participation With Cardiovascular Disease Risk in Children (the CHAMPS Study-DK). Mayo Clinic proceedings. 2017;92(1):57-65.
4. Hebert JJ, Moller NC, Andersen LB, Wedderkopp N. Organized Sport Participation Is Associated with Higher Levels of Overall Health-Related Physical Activity in Children (CHAMPS Study-DK). PloS one. 2015;10(8):e0134621.
5. Rossler R, Donath L, Verhagen E, Junge A, Schweizer T, Faude O. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. Sports medicine (Auckland, NZ). 2014;44(12):1733-48.
6. Finch C. A new framework for research leading to sports injury prevention. J Sci Med Sport. 2006;9(1-2):3-9; discussion 10.
7. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. Br J Sports Med. 2013;47(8):495-502.
8. Andersen CA, Clarsen B, Johansen TV, Engebretsen L. High prevalence of overuse injury among iron-distance triathletes. Br J Sports Med. 2013;47(13):857-61.
9. Ekegren CL, Gabbe BJ, Finch CF. Injury reporting via SMS text messaging in community sport. Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention. 2014;20(4):266-71.
10. Moller M, Attermann J, Myklebust G, Wedderkopp N. Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. British journal of sports medicine. 2012;46(7):531-7.
11. Moller M, Wedderkopp N, Myklebust G, Lind M, Sorensen H, Hebert JJ, et al. Validity of the SMS, Phone, and medical staff Examination sports injury surveillance system for time-loss and medical attention injuries in sports. Scand J Med Sci Sports. 2017.
12. Fuller CW, Ekstrand J, Junge A, Andersen TE, Bahr R, Dvorak J, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Scand J Med Sci Sports. 2006;16(2):83-92.
13. Clarsen B, Ronsen O, Myklebust G, Florenes TW, Bahr R. The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes. Br J Sports Med. 2014;48(9):754-60.
14. Brukner P, Khan K. Clinical Sports Medicine: McGraw-hill Professional; 2006.
15. Ekegren CL, Gabbe BJ, Finch CF. Injury surveillance in community sport: Can we obtain valid data from sports trainers? Scandinavian journal of medicine & science in sports. 2015;25(3):315-22.
16. Byrt T, Bishop J, Carlin JB. Bias, prevalence and kappa. J Clin Epidemiol. 1993;46(5):423-9.

17. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. Physical therapy. 2005;85(3):257-68.
18. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159-74.
19. Bland JM, Altman DG. Applying the right statistics: analyses of measurement studies. Ultrasound Obstet Gynecol. 2003;22(1):85-93.
20. Clausen MB, Zebis MK, Moller M, Krustrup P, Holmich P, Wedderkopp N, et al. High injury incidence in adolescent female soccer. Am J Sports Med. 2014;42(10):2487-94.
21. Nilstad A, Bahr R, Andersen TE. Text messaging as a new method for injury registration in sports: a methodological study in elite female football. Scand J Med Sci Sports. 2014;24(1):243-9.
22. Jespersen E, Holst R, Franz C, Rexen CT, Klakk H, Wedderkopp N. Overuse and traumatic extremity injuries in schoolchildren surveyed with weekly text messages over 2.5 years. Scandinavian journal of medicine & science in sports. 2014;24(5):807-13.
23. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study. Br J Sports Med. 2014;48(17):1327-33.
24. Meeuwisse WH, Tyreman H, Hagel B, Emery C. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clin J Sport Med. 2007;17(3):215-9.

TABLES AND FIGURES

Table 1. Demographics of study population

	Sub sample for comparison (n=271)	**All** (n=679)
Sex		
Boys n (%)	152 (56)	372 (55)
Girls n (%)	119 (44)	307 (45)
Age Group		
U16 n (%)	83 (31)	240 (35)
U18 n (%)	188 (69)	439 (65)
Mean Age (sd)		
Player position		
Back players n (%)	123 (45)	306 (45)
Wing players n (%)	63 (23)	170 (25)
Line players n (%)	47(17)	106 (16)
Goal keepers n (%)	38 (14)	97 (14)
Mean years handball experience (sd)	9.07 (2.87)**	9.29 (3.94)*
Mean hours weekly handball training (sd)	5.37 (1.41)****	5.38 (1.37)***

* Missing data from 17 players ** Missing data from 5 players *** missing data from 7 players **** missing data from 4 players.

Table 2. Injury registrations by SPEx and OSTRC telephone interviews.

	Comparison Method (Modified OSTRC approach)			
SPEx	No injury	Injury	Unknown injury status due to missing responsens	Total
No injury	106	15	64	185
Injury	0	21	22	43
Unknown injury status due to missing responses	14	9	20	43
Total	120	45	106	271

Table 3. Detailed description of injury registrations not captured by SPEx compared to OSTRC (phone) when all missing answers from both methods are dropped.

ID	Previously registered by SPEx	OSTRC Q1	OSTRC Q2	OSTRC Q3	OSTRC Q4	OSTRC score	Reason for not registered by SPEx
1	Yes. The week before	3	2	2	3	46	
2	No	1	1	1	2	8	Did not consider this as any physical problem
3	Yes. The week before	2	1	2	3	31	
4	Yes. The week before	2	1	1	1	8	
5	Yes, 3 weeks before	2	1	2	2	22	
6	Yes, the week before	4	5	3	2	71	This week the players also had the flu and registered that instead
7	Yes, 10 weeks before	1	1	2	3	23	
8	No	1	1	1	2	8	Did not consider this as any injury/problem
9	no	2	1	1	2	16	
10	no	1	1	1	2	8	Only a bit sore during warm up
11	no	1	1	1	2	8	Did not consider this as any injury/problem
12	no	1	1	2	2	14	
13	no	2	1	1	3	31	
14	no	2	1	1	3	25	
15	no	1	1	1	2	8	Bruises

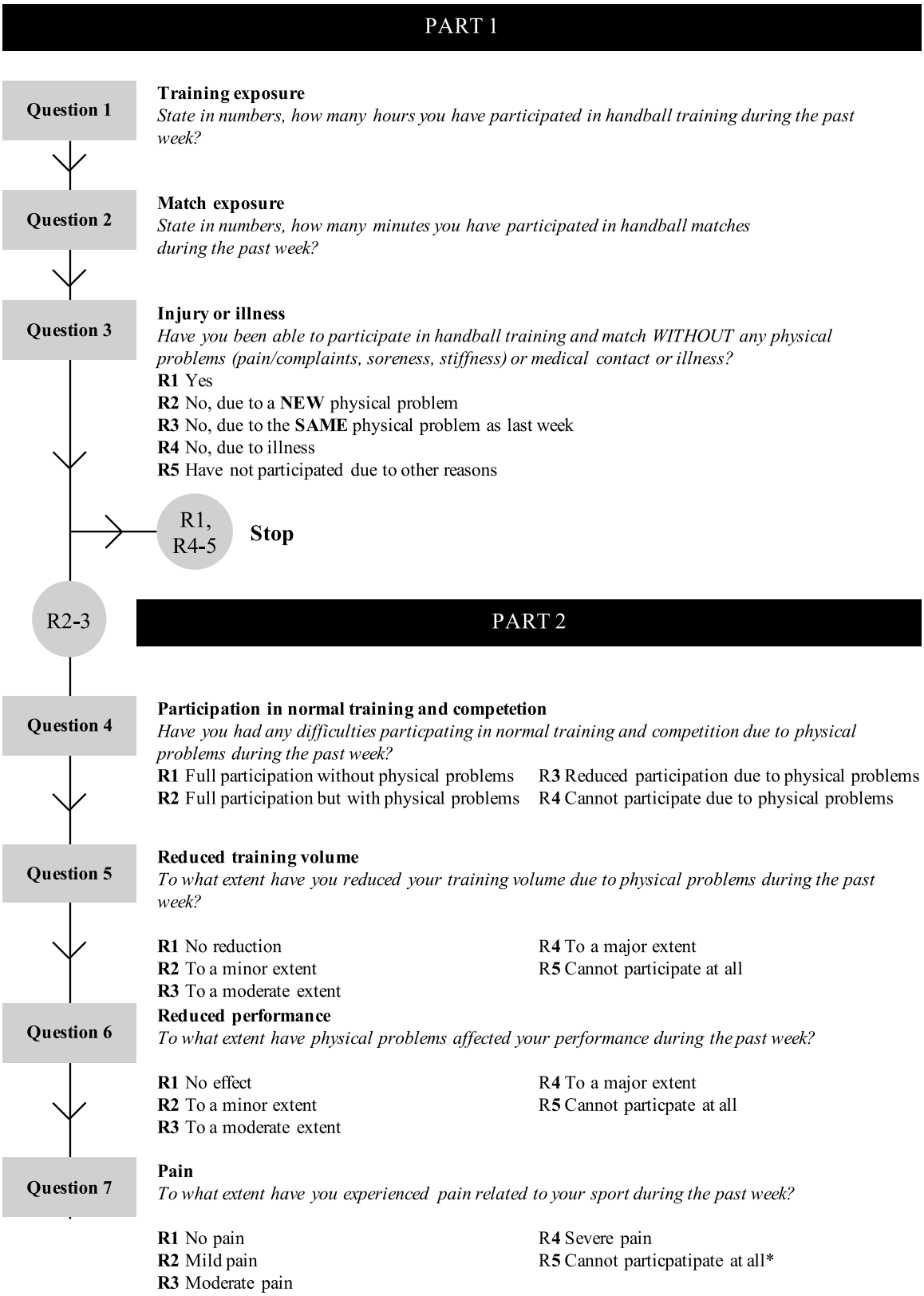

Figure 1. The SMS messaging part of the SPEx injury surveillance system. *extra added response possibility compared to the original OSTRC overuse injury questionnaire.

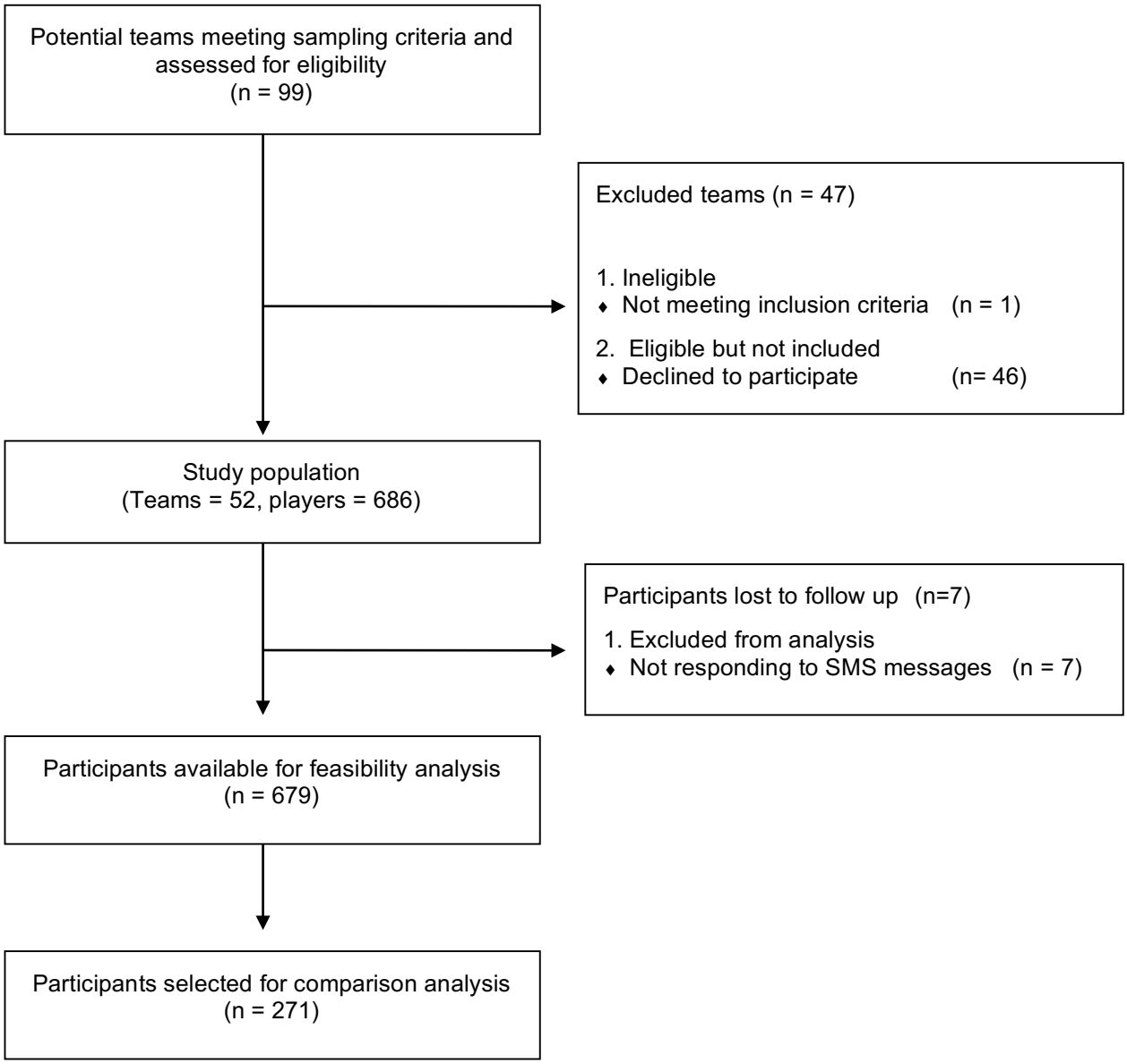

Figure 2. Study flow diagram.

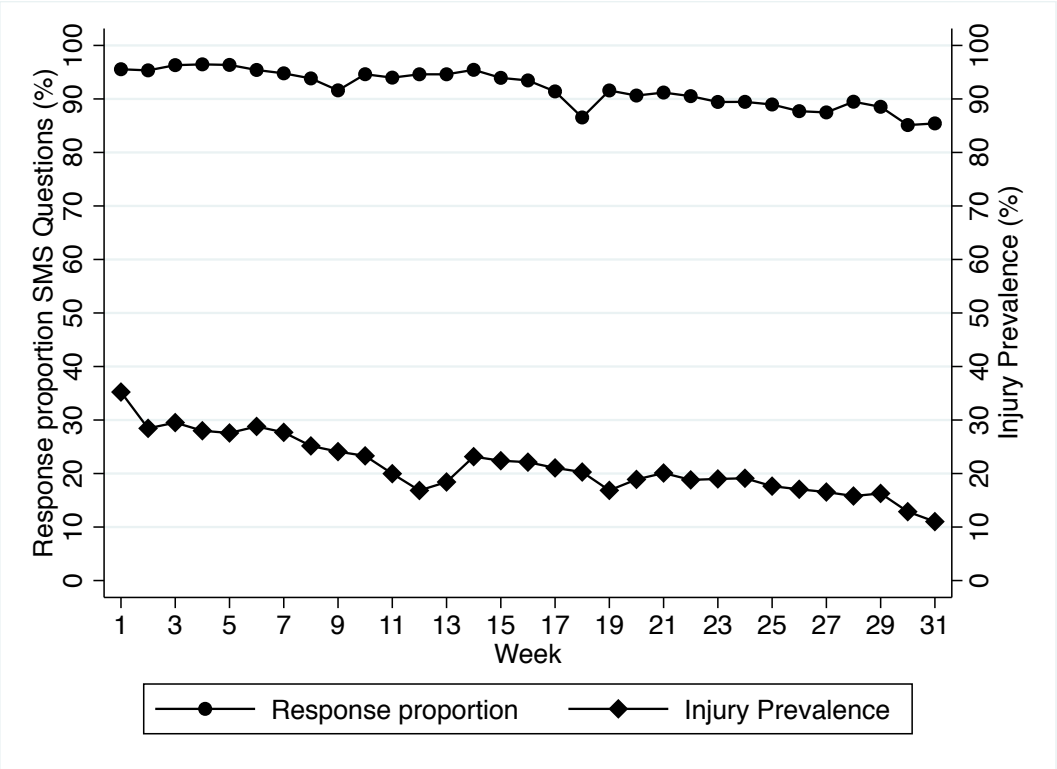

Figure 3. Response proportion to part 1 SMS injury questions in the SMS, Phone, and Physical Examination (SPEx) system (Figure1), and the prevalence of injuries reported by players via SPEx each week during one adolescent handball season.