Development of the Identification of Functional Ankle Instability (IdFAI)

Janet Simon, MS, ATC[1]; Matthew Donahue, PhD, ATC[2]; Carrie Docherty, PhD, ATC[3]

Bloomington, IN

ABSTRACT

Background: Self-reported questionnaires are a common method used in identifying individuals with ankle instability. Recently a study illustrated the singular use of any of the most frequently utilized questionnaires failed to significantly predict ankle stability status. Therefore, the purpose of this article was to present information related to the development of the Identification of Functional Ankle Instability (IdFAI). *Methods:* Volunteers (*n* = 278; 125 males, 153 females, 19.8 ± 1.4 years) completed the IdFAI on one occasion. An exploratory factor analysis was conducted with principal axis factoring as the extraction method with varimax rotation. Additionally, a discriminant function analysis was conducted to identify a discrimination score and to evaluate the accuracy of the questionnaire. *Results:* The factor analysis revealed: factor 1 (four questions) explained 53.7% of the variance, factor 2 (four questions) with an additional 17.4%, and factor 3 (two questions) an additional 6.3%. Overall, these factors accounted for 77.4% of the variance. There was a distinct discrimination score of 10.3 to identify people who have the minimally accepted criteria for FAI. Overall, the IdFAI has an accuracy of 89.6%. *Conclusion:* This investigation showed that the IdFAI was a feasible and appropriate way to identify individuals with FAI. *Clinical Relevance:* We suggest clinicians and researchers utilize the IdFAI to identify individuals with functional ankle instability since it is a short, simple, easy questionnaire to administer and take, and has been shown to have excellent accuracy.

[1] Associate Instructor, Indiana University, Bloomington, IN.

[2] Associate Instructor, Indiana University, Bloomington, IN.

[3] Associate Professor, Indiana University, Bloomington, IN.

Corresponding Author:
Janet Simon, MS, ATC
2805 E. 10th Street
Bloomington, IN 47408
E-mail: jesimon@indiana.edu

INTRODUCTION

In the years since the term "functional ankle instability" (FAI) appeared in the literature, numerous manuscripts have demonstrated that some individuals suffer from lasting deficits following an ankle sprain. [2,3,9,11,12,16,19,25,26] One of these lasting deficits, incidents of the ankle "giving way", is reported in 40% to 60% of individuals who suffer at least one ankle sprain.[3,12,16,19,26] Individuals reporting giving way in the absence of a mechanical deficit are usually classified as having FAI. However, FAI lacks a universally accepted definition or "gold standard" measure thus investigators are forced to set their own inclusion and exclusion criteria when examining these populations. Many investigators have utilized various self-reported questionnaires' in an effort to obtain homologous populations. A recently published study[6] illustrated that the singular use of any of the seven most frequently utilized questionnaires in the literature failed to significantly predict ankle stability status. But when the two of these questionnaires, Ankle Instability Instrument (AII) and Cumberland Ankle Instability Tool (CAIT), were used in conjunction they were able to predict the minimal acceptable criteria for functional ankle stability status with 84% accuracy. But this does not mean that the combined use of the AII and CAIT is the best possible solution.

We believe that the next logical steps in improving FAI research are to clearly define "giving way" since it is the most historically referred to symptom in people with FAI and to develop and implement a self-reported questionnaire based on the AII and CAIT designed to specifically detect characteristics of FAI. We believe in order to accomplish these goals a new questionnaire must clearly define the term "giving way," be sensitive to the deficits associated with FAI yet be concise and easy to administer for both the participant and investigator. Therefore, the purpose of this article was

to detail the creation and development of the Identification of Functional Ankle Instability (IdFAI).

MATERIALS AND METHODS

Participants

College-aged students were recruited from a large Midwestern university. Two-hundred seventy-eight college aged participants (125 males, 153 females; 19.8 ± 1.4 years of age) volunteered to participate in the study. Participants were not screened for mechanical ankle instability prior to completing the questionnaire. Limb dominance of the participants were 248 (89.2%) right leg, and 30 (10.8%) left leg. Individuals with a history of an ankle sprain were 211 (75.9%) and 67 (24.1%) without a history of ankle injury. Of the injured participants, 64 (30.3%) had sprained the right ankle only, 27 (12.8%) had sprained only the left ankle, and 120 (56.9%) had an ankle sprain on both left and right ankles. All participants gave informed consent and the university institutional review board approved this study.

Procedures

Participants were asked to complete the IdFAI on one occasion and data collection was done in the classroom setting. An investigator was present during all testing sessions and made certain that no outside distractions occurred during the testing period. Individuals were allowed as much time as necessary to complete the survey but normally participants finished in approximately 10 minutes.

Instrument development

The investigators recently reviewed the foot and ankle literature while conducting a preliminary research study on current ankle instability questionnaires. This experience provided necessary insight into historical and contemporary FAI inclusion criteria used in previously published work. This process identified seven instruments that are currently cited in the FAI literature.[5,7,15,18,20,22,23] The preliminary study revealed that the combination of two of these instruments (the AII and CAIT) best predicted the minimum criteria believed necessary to warrant classification as FAI.[6] For this reason the investigators based the initial IdFAI instrument on these two questionnaires. Therefore, the initial instrument contained 28 questions about ankle instability. These questions focused on the history of ankle sprains, presence and severity of ankle instability, and functional performance.

Statistical analysis

Question reduction

Data collected from the questionnaires were first reduced based on frequency of responses for each question. Questions were deleted if they did not receive an affirmative response ("yes") from at least 20% of the participants (56 people). This is a standard procedure in question reduction and supported

by Johnson and Wichern.[21] If these questions were included it could degrade the results because only a fraction of the participants reported answering "yes" to the question. An exploratory factor analysis was conducted on the remaining questions. A principal axis factoring extraction method with varimax rotation was utilized. Factors were included if they had an eigenvalue greater than 1.0 and explained greater than 5.0% of the variance.

Discriminative validity

Additionally, a discriminant function analysis was conducted after the factor analysis to identify a discrimination score. The discrimination score was tested to determine if the IdFAI could discriminate between individuals with and without FAI. The first step in the process was to determine the discrimination (cutoff) score that best differentiated between subjects with and without an ankle sprain and giving way. Because there was no criterion standard for measuring FAI, we used a minimum acceptable criterion for FAI, as history of an ankle sprain and giving way (MC_FAI) as the discriminative measure.[6] Individuals without an ankle sprain and giving way would be expected to score lower on the questionnaire, and those who have had an ankle sprain and giving way would be expected to score higher. The discrimination score was calculated by using the means of each group represented by the equation $(\overline{Y}_1 + \overline{Y}1) * 0.5$. The second step was to calculate the Youden index to confirm the results of the discrimination score. Youden index is calculated as (sensitivity + specificity -1.0). A receiver operating curve (ROC) was also constructed to confirm the cutoff point.

Accuracy of the IdFAI

The questions retained from the factor analysis were used as predictor variables, and membership in the group (no MC_FAI and MC_FAI) was used as the dependent (grouping) variable for the discriminant function analysis. In order to determine the accuracy of the questionnaire in separating individuals with and without FAI we again utilized the minimal acceptable criteria for Function Ankle Instability (MC_FAI). Individuals that had a history of an ankle sprain and giving way were classified as "MC_FAI"

Table 1: Cumulative Variance and Eigen Value for the Three Retained Factors from the Exploratory Factor Analysis

	Factor 1	Factor 2	Factor 3
Proportion of Variance	53.7%	17.4%	6.3%
Cumulative Variance	53.7%	71.1%	77.4%
Eigen Value	5.79	1.88	1.10

Table 2: Factor Analysis Rotated Component Matrix (Factor Loadings)

Question	Factor 1	Factor 2	Factor 3
Factor 1			
Q10-During Sport/or recreational activities how often does your ankle feel unstable?	0.71		
Q5- When was the last time you had "giving way" in your ankle?	0.68		
Q6- How often does the "giving way" sensation occur in your ankle?	0.62		
Q7- Typically when you start to roll over (or 'twist') on your ankle can you stop it?	0.57		
Factor 2			
Q1- Approximately how many times have you sprained your ankle?		0.77	
Q2- When was the last time you sprained your ankle?		0.73	
Q4- If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?		0.53	
Q3- If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?		0.51	
Factor 3			
Q8- Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?			0.73
Q9- During "Activities of daily life" how often does your ankle feel unstable?			0.70

and for individuals with, no history of and ankle sprain and giving way, were classified as "no MC_FAI".

RESULTS

Question reduction

Fourteen questions were deleted based on the 20% of responses criteria. This means that less than 56 people experienced what the question was asking. The 14 questions that were deleted were related to ankle instability during: walking-flat surfaces ($n = 7$, 2.5%), walking-upstairs ($n = 5$, 1.8%), walking-downstairs ($n = 8$, 2.9%), making sharp turns-walking ($n = 20$, 7.2%), standing-one leg ($n = 37$, 13.3%), standing-ball of your foot ($n = 17$, 6.1%), hopping-one foot ($n = 45$, 16.2%), and hopping-side to side ($n = 30$,

10.8%); and ankle pain during: walking-level surfaces ($n = 3$, 1.0%), walking-uneven surfaces ($n = 13$, 4.7%), during daily activity ($n = 7$, 2.5%), during sports ($n = 44$, 15.8%), running-uneven surfaces ($n = 44$, 15.8%), and running-level surfaces ($n = 10$, 3.6%). This left 14 questions for the exploratory factor analysis.

The factor analysis revealed ten questions that fit into three factors (Appendix A) that met the criteria of an eigenvalue of 1.0 and had a proportion of more than 5.0% of the variance (Table 1). Four questions were not retained in the questionnaire because they did not fit in the model. Factor 1 included four questions (Q10, Q5, Q6, and Q7) and accounted for 53.7% of the variance. Factor 2 included 4 questions (Q1, Q2, Q4, and Q3) and accounted for an additional 17.4% of the variance. Factor 3 included 2

Table 3: Determination of Discrimination Score for Functional Ankle Instability Based on the Youden's Index

IdFAI Score	8.0	9.0	10.0	11.0	12.0
Sensitivity	0.92	0.87	0.83	0.79	0.72
Specificity	0.67	0.74	0.94	0.94	0.97
Youden index*	0.59	0.61	0.77	0.73	0.69
+Likelihood Ratio	2.79	3.30	13.83	13.17	24.00
− Likelihood Ratio	0.12	0.18	0.18	0.22	0.29
Odds Ratio	23.25	18.33	76.83	59.86	82.76

*Youden's index was maximum, with a discrimination score of 10.0

questions (Q8, and Q9) and accounted for an additional 6.3% of the variance. Overall, these 3 factors accounted for 77.4% of the variance in the responses to the IdFAI. Questions and the factor loadings are shown in Table 2. For this analysis, the suppression threshold was set at 0.50. At this threshold, each question only loaded into one factor.

Discriminative validity

There was a distinct discrimination score from the discriminant function analysis and was calculated from the mean of the no MC_FAI group and MC_FAI group, $(5.4 + 15.2)*0.5 = 10.3$, (range, 0 to 37) for determining whether or not an individual had experienced an ankle sprain and giving way. The discrimination score also corresponded to the highest Youden's index of 0.77, which is an additional technique to determine a discrimination score (Table 3). Individuals with a score of 10 or lower were unlikely to have FAI, where as individuals with a score of 11 or higher were likely to have FAI (Figure 1). The ROC curve is shown in Figure 2. The area under the ROC curve is 0.91 (range, 0.88 to 0.94); this indicates that the IdFAI was excellent at separating the two groups of ankle sprain and giving way and no ankle sprain and no give way.

Accuracy of the IdFAI

The accuracy of the questionnaire was evaluated by the discriminant function analysis from a 2x2 contingency table based on the discrimination score (Table 4). The accuracy of the IdFAI "diagnosing" an individual as No_MC FAI and
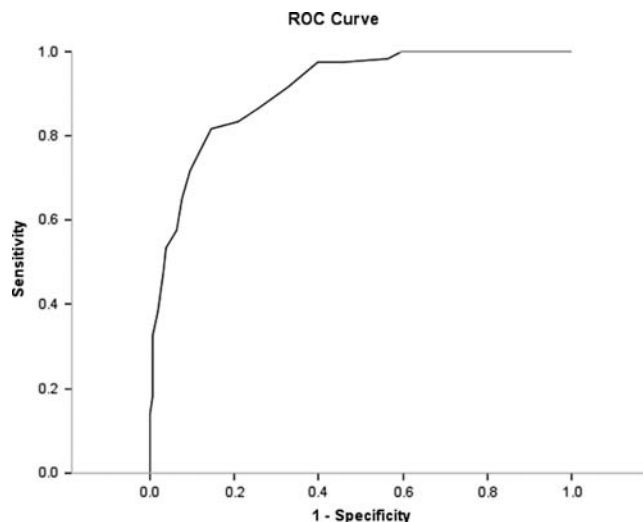

Fig. 2: Receiver operating characteristic curve illustrates the tradeoff between sensitivity and specificity (area under the curve = 0.91).

they actually met the criteria of No_MC FAI was 88.2%. The accuracy of the IdFAI "diagnosing" an individual as MC_FAI when they met the criteria of MC_FAI was 91.7%. Overall, the IdFAI had an accuracy of 89.6%.

DISCUSSION

The existence of lasting deficits after ankle injury is well established,[1,10,14,17] but little else is universally agreed upon. Recently, a systematic review of ankle instability literature compiled 118 research studies and found over 90 variations of inclusion criterions.[4] Nearly all variations required that the participant experience at least one ankle sprain and most required that participants described previous incidents of giving way.

During the design and execution of the IdFAI we had three categories of concern: instrument design, threshold for identification, and burden. These categories were created based on recommendations for quality-of-life instruments set forth by the Scientific Advisory Committee of the Medical Outcomes Trust.[24]
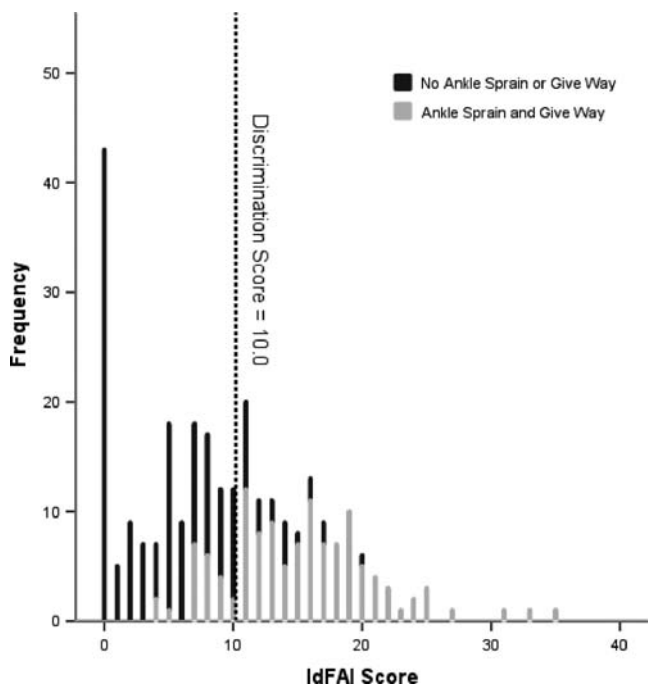

Fig. 1: Distribution of participants along the IdFAI showing those with and those without a history of ankle sprain and giving way (Discrimination Score 10.0).

Table 4: 2 × 2 Contingency Table to Determine Accuracy of the IdFAI

	No MC FAI	MC FAI	Totals
IdFAI No FAI	149	20	169
IdFAI FAI	9	100	109
Totals	158	120	278

*Based on the discrimination score of 10.0

Instrument design

Many currently utilized instruments exist in multiple versions, designs, or layouts some of which contain varying content or question wording from version to version. A number of these instruments were originally designed to be utilized in a clinical intake or other non-research related settings. As a result some instruments were significantly longer than others, ranging from one to four pages.[5,7,13,15,20,22] Some included clear and concise directions while others offered confusing or limited directions to participants. Many of the included measures dealt with limbs differently, some asked participants to complete the same form for each limb,[5,8,18,20,22] one asked questions with a response for each limb,[15] and another asked participants to answer based on a comparison of their limbs.[23] Based on the information taken from these questionnaires, we felt that the questionnaire should fit on one page, provide clear directions, and complete the same questionnaire for each limb. Completing the same questionnaire for each limb allowed individuals with bilateral ankle symptoms to take the questionnaire independently for each limb.

A systematic review also identified that nearly all ankle instability publications mention incidents of "giving way" as one aspect of their inclusion criteria but nearly all fail to clearly define "giving way" or how it should be explained to the participant.[4] With this evidence we decided to clearly define "giving way." This ensured that each participant was not left to their own devices to define "giving way." We defined "giving way" based on the research conducted by Delahunt[4] as: a temporary uncontrollable sensation of instability or rolling over of one's ankle. Again, this allowed all participants to answer any 'giving way' questions based on the same knowledge.

Threshold for identification

While a discrimination score or threshold of detection can be found in the literature for all of the other questionnaires, the origin, validity and universal application was not documented for all measures. For the creation of the IdFAI we wanted to explain the discrimination score and how we arrived at the particular score. To do this a discriminant function analysis and Youden index was utilized. The discrimination score distinguished between two groups. In this study, group membership was based on the minimally acceptable criteria for FAI (MC_FAI). The MC_FAI was previously utilized in a research study[6] conducted in our laboratory and was constructed based the working definitions of functional ankle instability in the existing literature. In the existing literature there are consistent reports that individuals included in FAI populations should at minimum report an initial ankle sprain and incidents of "give way" in the same ankle. It is our belief that these findings, when combined with our previous research support the use of the MC_FAI utilized in this paper for the discriminant function analysis. The use of MC_FAI allowed the comparison of the IdFAI on this

basic set of symptoms. However, using the MC_FAI criteria does not distinguish or rule out other conditions such as mechanical ankle instability, nor does it provide any insight into severity of FAI. However, since no universally accepted definition of FAI exists, the minimum criterion for FAI was used.

The discriminant function analysis and Youden Index both yielded discrimination scores of 10. Matching Youden Index and the discriminant function analysis scores validate the discrimination score of 10. The accuracy of the IdFAI in separating individuals with and without FAI was re-evaluated based on the new discrimination score. Overall, the IdFAI had excellent accuracy of 89.6%. The previous study that resulted in the combined use of the AII and CAIT having the best accuracy of identifying individuals with FAI had an overall accuracy of 84.6%. Specifically, the combined use of the AII and CAIT for No MC_FAI = 95.7%, MC_FAI = 55.6%; on the other hand the accuracy of IdFAI for No MC_FAI = 88.2% and MC_FAI = 91.7%. Using the AII and CAIT were better at determining people who did not have FAI (AII and CAIT = 95.7%, IdFAI = 88.2%); while the IdFAI was better at determining people who did have FAI (IdFAI = 91.7%, AII and CAIT = 55.6%). Even though there was a decrease in the accuracy of determining who did not have FAI, the overall accuracy of the IdFAI was better and the increase in accuracy (36.1%) of determining people who had FAI was substantial. After comparing these results, the use of the IdFAI should allow for better accuracy in "diagnosing" individuals with FAI.

Burdens

Two major recommendations for the design of quality-of-life instruments pertain to the burdens placed on both the participants (respondent) and administrator.[24] The recommendations defined a burden as the time, effort and other demands placed on the respondent and administrator.[24] When creating the IdFAI we wanted to create an instrument with the lowest possible burden to both the respondents and administrator. The burdens to the respondents include the length and ease of taking the questionnaire. The length of the IdFAI is rather short being one page in length and on average took respondents less than 5 minutes to take. The IdFAI is also quite easy for the respondents to take because the questions are simple to answer with having the respondent "tick" answer boxes. The burdens to the administrator include resources required to administer (paper, number of copies) and the amount of training or education necessary to score. The IdFAI is only one page so it has decreased administrative burdens in the production and storage of the measure. Scoring the IdFAI is also quite easy for administrators because the administrator adds up each ordinal question for the total score. This scoring method allows for decreased possibility for confusion and miscalculation (range, 0 to 37) (Appendix B).

IdFAI factors

As previously mentioned, analysis of the IdFAI revealed three specific factors. Factor 1 (history of ankle instability) included questions concerning feelings of instability during sports/recreational activities, the last time giving way episodes occurred, how often giving way occurs, and ability to stop ankle from continuing to roll over. These questions combined to reflect the general sense of ankle instability. Some of these questions have been used in previous FAI literature, but this factor is considered the "new factor" (questions that are not exclusively on the AII or CAIT). FAI implies disability during activity, and this factor addressed this component in addressing the presence of FAI.

In Factor 2 (initial ankle sprain), analysis revealed questions such as how many ankle sprains the individual sustained, time since last ankle sprain, time weightbearing assistance was needed, and grade of ankle sprain diagnosed by a healthcare provider. We feel Factor 2 provided a good representation of the severity of the preceding ankle sprain. These questions have been previously documented in the literature, particularly on the AII. This factor should provide a better assessment of the severity of previous ankle sprains.

Factor 3 (instability during activities of daily living) was comprised of questions such as length of time following an ankle sprain required for the ankle to return to normal, as well as questions concerning instability during activities of daily living. These questions reflected instability during activities of daily motion. This was different from Factor 1 since it was related to more non-sports specific motion. The occurrence of instability during normal activities represented possibly significant instability that affects individuals on a frequent or daily basis, and indicates the presence of ongoing instability. The questions in this factor represent questions originally found on CAIT.

The IdFAI can provide both clinicians as well as researchers with a meaningful and objective way of examining individuals with FAI. Based on the data provided we believe the IdFAI can accurately establish an individual's ankle stability status by gathering relevant information from the ten questions. In the future we hope to determine the severity of FAI using the IdFAI because all questions are ordinal in nature and the answers to the IdFAI can simply be added to create an FAI score which can be used to create a spectrum and establish severity of FAI. For example, people who score higher on the IdFAI may have more severe FAI symptoms which may correlate with clinical ankle instability testing. For example, higher scores on the IdFAI (more severe FAI) may correlate with increased postural sway. Clinicians will also be able to have athletes or patients take the IdFAI and chart their progress as they advance through rehabilitation or identify people at risk and implement a rehabilitation program.

CONCLUSION

Nearly all ankle instability research utilizes some form of subjective self-reported measure to identify participants with FAI. We believe the IdFAI is a starting point to begin the process of creating a universally accepted definition of FAI. This investigation showed that the IdFAI was a feasible and appropriate way to obtain information on identifying individuals as having FAI. We propose that the IdFAI be used in the identification of FAI in individuals because it is a short, simple, easy questionnaire to administer and take, and it has been shown to have excellent accuracy in identifying individuals with FAI correctly.

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Appendix A. Final IdFAI

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? _____

2.) When was the last time you sprained your ankle?

❏Never   ❏ > 2 years   ❏ 1-2 years   ❏ 6-12 months   ❏ 1-6 months   ❏< 1 month

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

❏Have **not** seen someone   ❏Mild (Grade I)   ❏Moderate (Grade II)   ❏Severe (Grade III)

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

❏Never used a device   ❏1-3 days   ❏4-7 days   ❏1-2 weeks   ❏2-3 weeks   ❏>3 weeks

5.) When was the last time you had **"giving way"** in your ankle?

❏Never   ❏> 2 years   ❏1-2 years   ❏6-12 months   ❏ 1-6 months   ❏< 1 month

6.) How often does the **"giving way"** sensation occur in your ankle?

❏Never   ❏Once a year   ❏Once a month   ❏Once a week   ❏Once a day

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?

❏Never rolled over   ❏Immediately   ❏Sometimes   ❏Unable to stop it

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?

❏Never rolled over   ❏Immediately   ❏ < 1 day   ❏1-2 days   ❏> 2 days

9.) During "Activities of daily life" how often does your ankle feel **UNSTABLE**?

❏Never   ❏Once a year   ❏Once a month   ❏Once a week   ❏Once a day

10.) During "Sport/or recreational activities" how often does your ankle feel **UNSTABLE**?

❏Never   ❏Once a year   ❏Once a month   ❏Once a week   ❏Once a day

Appendix B. IdFAI Scoring

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? _____

2.) When was the last time you sprained your ankle?

❑ Never   ❑ > 2 years   ❑ 1-2 years   ❑ 6-12 months   ❑ 1-6 months   ❑ < 1 month
   0   1   2   3   4   5

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

❑ Have **not** seen someone   ❑ Mild (Grade I)   ❑ Moderate (Grade II)   ❑ Severe (Grade III)
       0   1   2   3

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

❑ Never used a device   ❑ 1-3 days   ❑ 4-7 days   ❑ 1-2 weeks   ❑ 2-3 weeks   ❑ >3 weeks
      0   1   2   3   4   5

5.) When was the last time you had *"giving way"* in your ankle?

❑ Never   ❑ > 2 years   ❑ 1-2 years   ❑ 6-12 months   ❑ 1-6 months   ❑ < 1 month
   0   1   2   3   4   5

6.) How often does the *"giving way"* sensation occur in your ankle?

❑ Never   ❑ Once a year   ❑ Once a month   ❑ Once a week   ❑ Once a day
   0   1   2   3   4

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?

❑ Never rolled over   ❑ Immediately   ❑ Sometimes   ❑ Unable to stop it
     0   1   2   3

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?

❑ Never rolled over   ❑ Immediately   ❑ < 1 day   ❑ 1-2 days   ❑ > 2 days
     0   1   2   3   4

9.) During "Activities of daily life" how often does your ankle feel *UNSTABLE*?

❑ Never   ❑ Once a year   ❑ Once a month   ❑ Once a week   ❑ Once a day
   0   1   2   3   4

10.) During "Sport/or recreational activities" how often does your ankle feel *UNSTABLE*?

❑ Never   ❑ Once a year   ❑ Once a month   ❑ Once a week   ❑ Once a day
   0   1   2   3   4