The Landing Error Scoring System Real-Time (LESS-RT) As a Predictive Tool for Overuse Injuries and Ankle Sprain: A Historical Cohort Study.

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Abstract

Background:

Overuse injuries and ankle sprains are commonly sustained by soldiers and athletes during conditioning programs and may have significant ramifications on both individuals and organizations. The Landing Error Scoring System (LESS), and its expedited real-time version (LESS-RT) were developed to assess risk for ACL injuries, but have never been used to assess overuse or ankle injuries which are of high priority in a military or athletic settings. The purpose of this study was to evaluate predictive value of The Landing Error Scoring System Real-Time (LESS-RT) for overuse injuries of the lower limb and ankle sprains among Israel Defense Forces (IDF) combat soldiers.

Methods:

A historical cohort study was conducted on 2,474 IDF combat soldiers from different service units with a wide range of fitness levels and training requirements. The predictive variable was LESS-RT score and the outcome variables were the incidence of overuse injuries and ankle sprains. Receiver operator characteristic curves were used to assess the predictive value of LESS-RT for both outcomes.

Results:

The AUC for overuse injuries and ankle sprains were 0.537, 95% CI 0.514-0.560 and 0.523, 95% CI 0.491-0.556 respectively.

Conclusions:

The results of this study shows no predictive value of LESS-RT score for both overuse injuries of the lower limb and ankle sprains.

Introduction:

Overuse Injuries & ankle sprains:

Overuse injuries result predominantly from long and repetitive training sessions and are recognized as the leading cause of lost training days and attrition from combat units in armies around the world, including the Israel Defense Forces (IDF) ¹⁻⁴. Furthermore, a recent study conducted in the IDF demonstrated that overuse injuries account for 90% of all orthopedic injuries, which are far and away the leading cause of medical attrition from both infantry and non-infantry combat training units². Due to the significant loss of training days and attrition rates², these injuries may substantially reduce the readiness of combat units to perform their mission. Furthermore, in severe cases, overuse injuries may be complicated with irreversible tissue damage and permanent disability³⁻⁶.

Ankle sprains are among the most common injuries and have the potential to be complicated by permanent ankle instability, which can cause significant disability and discharge from combat service^{7,8}. In the US army, the incidence rate of ankle sprains is 35 cases per 1000 person-years with a higher risk for women, (41 cases per 1000 person-years)⁹. These sprains are second only to low back pain with regards to lost training days and rehabilitation workload^{10,11}. The significant incidence, comorbidity and ramifications of overuse injuries and ankle sprains on both soldiers and athletes make their prevention a public health issue of high priority^{2,6,10}.

The Importance of Prediction Tools for Injury Prevention:

Clinical prediction tools are used to screen a large volume of patients with the aim of identifying risk factors associated with injury.^{12,13} Clinical movement screening tests refer to a subset of prediction tools focusing on the assessment of specific biomechanical or anatomical risk factors^{12,13}. The latter, attempt to assess the risk for different musculoskeletal injuries and may facilitate the establishment of intervention plans geared towards injury prevention¹⁴⁻¹⁷.

The Landing Error Scoring System:

The Landing Error Scoring System (LESS) is a prediction tool originally developed for assessing the risk for ACL (Anterior Cruciate Ligament) injuries¹⁸⁻²¹. The test aims to assess injury risk by evaluating subjects' biomechanical landing errors via 17 different scoring criteria, encountered during a three-step jump landing task. The task, which involves jumping from a 30cm high platform, landing and proceeding to perform an additional jump, is traditionally video recorded. The latter recording then serves raters to tally a cumulative injury risk score^{18,22,23}. The LESS test has shown reliability and validity in assessing risk for ACL injuries among soldiers and athletes^{18,19}, prompting research of its predictive validity of other musculoskeletal injuries²²⁻²⁴. as well as an expedited, real-time version of the test²⁵. However, the LESS' validity, and reliability are still questionable, partially due to the use of subjective method of scoring.^{18,20,24-29}. Despite its limitations, the evidence supporting the use of LESS as a screening tool for identifying persons with risk for ACL injury^{19,29,30}, makes it a possibly applicable tool for use in a military setting, as part of a battery of screening tests³¹ for the evaluation of the risk for musculoskeletal injuries among soldiers.

The Real-Time version of LESS:

Since its inception in 2009¹⁸, several alternative variants of the LESS have been proposed^{25,32}. These variants aimed to create a more streamlined or reliable variant of the LESS, furthering its potential as a screening test. The Landing Error Scoring System-Real Time (LESS-RT), is an alternative variant of the LESS, which uses a confined set of scoring criteria to allocate injury risk score in real-time²⁵. The LESS-RT was studied in terms of interrater reliability and correlation with standard LESS scores demonstrating good interrater reliability and good correlation of the results with the results of the standard LESS test (range: 0.72 to 0.81 with standard error of measurements ranging from 0.69 to 0.79).²⁵

By omitting the need for video equipment, the LESS-RT test provides better accessibility and availability as compared to the classic version of LESS, with emphasis of field units.

In a previous study we found no predictive value of the LESS-RT test for knee overuse injuries, meniscal injuries, or ACL injuries³³. However, since biomechanical landing errors may affect forces distribution along the entire lower limb the LESS-RT test may have the potential to predict the risk for developing injuries in the lower extremity.

Purpose:

The purpose of this study was to evaluate the LESS-RT as a predictive tool for developing overuse injuries in the lower limbs and ankle sprains in particular.

Study hypothesis:

LESS-RT test can serve as an efficient predictive tool for both overuse injuries and ankle sprains.

Methods:

Study design Institutional Review Board approval:

We conducted a historical cohort study to evaluate the potential of the LESS-RT in predicting overuse injuries in general, and ankle sprains in particular among IDF combat soldiers. The predictive variable used in this study was LESS-RT score. Subjects were followed during a 12-month follow-up period beginning from the date of LESS-RT examination for two main outcome variables: 1. incidence of overuse injuries 2. Occurrence of ankle sprains.

This study was approved by the IDF's Institutional Review Board (IRB), (Approval number: 1634-2015). Data analysis was performed using anonymized databases after exclusion of all identifying details.

Overuse injury Definition:

Overuse injuries were tallied if they satisfied all of the following criteria:

1. At least two identical musculoskeletal complaints during a consecutive period of 2 weeks.
2. At least one objective sign upon physical examination.
3. A significant reduction in function or physical performance due to the complaint.

It should be emphasized that the term overuse is referred to the mechanism of the injury (eg. Injury caused by repetitive stress which accumulates to a significant process of wear, resulting in severe tissue damage and insufficiency). This mechanism may be responsible not only for chronic injuries but also for acute injuries where tissues like muscles, tendons and ligaments may abruptly collapse during mild to moderate physical efforts resulting in complete or partial tears.

Ankle sprains were diagnosed by IDF physicians and certified orthopedic surgeons affiliated with the IDF.

Re-injury was defined as recurrence of a specific injury within the 12-month follow-up period and these were not tallied as an additional injury.

Subjects:

All IDF's soldiers are medically screened before recruitment and only those that are medically fit for combat service will be recruited to combat units. In 2014, the IDF first instituted its "Injury Prevention and Rehabilitation Center" (IPARC). The primary objective of this center was to evaluate combat soldiers prior to and during their enrollment in combat military units. The soldiers evaluated at IPARC hail from a variety of IDF combat units with varying activity levels including infantry training units and brigades, Special Forces, and commanders training units (Phase 2 training). The superior command of the Israeli field forces decided which of the units would be screened at IPARC, hence, The study's population is not necessarily representing the entire IDF's combat soldier population. A total of 2,474 IDF soldiers assessed at IPARC within the first two years of its launch (2014-2016) were included in this study. Soldiers with any lower extremity injury (including overuse/ankle sprain) in the 3 months prior to performance of the LESS-RT examination or those with lower limb anatomical variations, (such as genu varus or valgus as documented by IDF physicians in the soldiers' medical records), were excluded. During the screening process at IPARC, the soldiers undergo a battery of clinical movement screening tests including the LESS-RT.

The screening at IPARC predominantly occurred during the first 6 month of the soldiers' military service.

LESS-RT test procedure:

The subjects in this study performed the LESS-RT according to the method outlined by Padua et al.²⁵ The three-step jump-landing task, which is identical to that of the original LESS, involves a forward jump from

a 30-cm-high box onto a target landing zone and is followed by an immediate rebound jump to maximal vertical height. The landing area is situated at an approximate distance of half of the participant's height^{18,19}. The LESS-RT uses 10 scoring items to identify gross movement errors²⁵. These are scored in real-time and the cumulative result is used to assess potentially high-risk jump-landing biomechanics¹⁸⁻²⁸. Half of the items are scored on a 2-point ordinal scale (0,1) and the other half on a 3-point ordinal scale (0, 1, and 2) (see table 1).

	LESS-RT Item	Rater Perspective	Maximum Score
1	Stance width	Frontal	1
2	Maximum foot-rotation position	Frontal	1
3	Initial foot contact	Frontal	1
4	Maximum knee-valgus angle	Frontal	2
5	Amount of lateral trunk flexion	Frontal	1
6	Initial landing of feet	Sagittal	1
7	Amount of knee-flexion displacement	Sagittal	2
8	Amount of trunk-flexion displacement	Sagittal	2
9	Total joint displacement in the sagittal plane	Sagittal	2
10	Overall impression	Both	2

Table 1. Items Scored in the in the Landing Error Scoring System-Real Time (LESS-RT)

The cumulative score ranges from 0 to 15 with lower scores indicating fewer accumulated biomechanical errors. The jump-landing task is repeated four times in order to enable ample time and reiteration for scoring the test in concurrence with its performance. Tests were assessed by IDF physical therapists who gauged two repetitions from the frontal plane, and two from the sagittal plane as performed in the study by Padua et al.²⁵ These scorers did not have previous experience in rating LESS or LESS-RT tests and the identity of the raters in each session was not recorded.

Data collection:

Soldiers' demographic data and LESS-RT scores were acquired from IPARC's computerized database. Data pertaining to medical history and incidence of overuse injuries and ankle sprains were collected from the IDF's computerized medical record system – CPR[®] with a follow-up period of one year from LESS-RT performance.

For optimal identification of overuse injuries and ankle sprains, ICD-9 diagnostic codes were used as well as a novel text identification program that was developed by the IDF's medical forces information branch. All data were anonymized and introduced into a Microsoft Office Excel® spreadsheet which served for further statistical analysis.

Statistical Analyses:

Statistical analysis was performed using SPSS® 23.0 (IBM SPSS Statistics, New York, USA). Descriptive statistics were calculated and displayed using means and standard deviations for continuous variables, median for scales, and frequencies for categorical variables. The chi-square test was used for the statistical significance when comparing two dichotomous variables.

Student's *t*-test was used to determine the statistical significance when comparing quantitative variables divided into 2 categories such as injury outcomes. Shapiro Wilks test was used to evaluate whether variables were normally distributed. . Mann–Whitney U test was used in case variables were normally distribution. The analysis of variance test (ANOVA) was used to assess statistical significance when comparing categorical variables of more than 2 groups. Receiver operator characteristic (ROC) analyses were performed to evaluate the LESS-RT's potential as a predictive tool for overuse injuries and ankle sprains and to potentially obtain optimal cut-off values for different risk categories.

Results:

2,474 soldiers evaluated at IPARC were included in this study. Of them, 1663, (67.2%) were males and 811 (32.8%) were females). The mean age was 19.4 ± 2.3 years, range: 17.5 – 23, the mean BMI was 23.2 ± 3.0 . Seventy-one percent of soldiers were in the normal BMI category (18-25). For a detailed demographic description of the study population, see Table 2.

Characteristic	Frequency	Relative Proportion /Mean $\pm$ SD, Median
Study Population	2,774	100%
Gender		
Male	1,663	67.2%
Female	811	32.8%
LESS-RT Score		Median 3 Range: 1-7
Age (years $\pm$ SD)		19.4 $\pm$ 2.3
Height (cm $\pm$ SD)		170.9 $\pm$ 8.6
Weight (kg $\pm$ SD)		67.7 $\pm$ 10.6
BMI (kg/m² $\pm$ SD)		23.2 $\pm$ 3.0
BMI Category		
<18	68	2.7%
18-25	1,767	71.4%
25-30	480	18.6%
30-35	51	2.1%
35<	13	0.5%
Missing	115	4.6%
Service Unit		
Infantry	736	29.7%
Special Units	357	14.4%
Non-infantry	277	11.2%
Home Front Command	465	18.8%
Commanders	639	25.8%

Table 2. Demographics and characteristics of the study population.

LESS-RT Scores of the study population:

The median LESS-RT score was 3. The most common LESS-RT score was 2 which was assigned to 26.9% of the soldier. LESS-RT score was not normally distributed (Shapiro Wilks test: $p < 0.001$).

Overuse Injuries:

Population Characteristics by Overuse Injuries:

During the one-year follow-up, 1,467 soldiers with overuse injury were identified (59.3% of the study population). Of these soldiers, 931 were males (56.0% of all males) and 536 were females (66.1% of all females). Approximately 50% of overuse injuries occurred during the first 2 months of training.

For detailed characteristics of the population divided by overuse injury status, see Table 3.

Table 3. Characteristics of study population divided by overuse injury status during a one-year follow-up.

LESS-RT Score by Overuse Injury Status:

Mann–Whitney U test was used to compare mean LESS-RT scores according to overuse injury status. The difference in median LESS-RT score was significantly higher in soldiers sustaining overuse injury as compared to those who did not; (3 vs. 5 $p = 0.01$).

ROC Analysis of Overuse Injuries:

ROC analysis was used to assess the LESS-RT's ability to predict overuse injuries in the study population. The ROC area under the curve (AUC) was 0.537 (95% CI 0.514-0.560). See Table 5.

Ankle Sprains:

Characteristic	Overuse Injury	No Overuse Injury	P value
Number (% from total)	1,467 (59.3)	1,007 (40.7)	
Gender			
Male (% within gender)	931 (56.0)	732 (44.0)	p<0.001
Female (% within gender)	536 (66.1)	275 (33.9)	
LESS-RT Score	5 Range: 3-10	3 Range: 1-7	p=0.01
Age (years ± SD)	19.4 ± 2.8	19.5 ± 1.4	p=0.090
Height (cm ± SD)	170.4 ± 9.0	171.7 ± 8.5	p<0.001
Weight (kg ± SD)	67.7 ± 10.8	67.8 ± 10.2	p=0.719
BMI (kg/m² ± SD)	23.3 ± 3.2	22.9 ± 2.8	p=0.007
BMI Category			
<18 (% within category)	41 (60.3)	27 (39.7)	p=0.026
18-25 (% within category)	1,017 (57.6)	750 (42.4)	
25-30 (% within category)	297 (64.6)	163 (35.4)	
30-35 (% within category)	31 (60.8)	20 (39.2)	
35< (% within category)	11 (84.6)	2 (15.4)	
Missing	115		
Service Unit			
Infantry (% within unit)	502 (68.2)	234 (31.8)	p<0.001
Special Units (% within unit)	191 (53.5)	166 (46.5)	
Non-infantry (% within unit)	117 (42.2)	160 (57.8)	
Home Front Command (% within unit)	326 (70.1)	139 (29.9)	
Commanders Training (% within unit)	331 (51.8)	308 (48.2)	

Population Characteristics by Ankle Sprain:

During the follow-up period, 352 (14.2%) soldiers were identified with ankle sprain, of them, 220 were male (13.2% of males) and 132 were female (16.2% of females). The risk of sustaining ankle sprain was significantly higher in females as compared to males (RR 1.28; 95% CI 1.01-1.61; p=0.042). The frequency of ankle sprains was significantly higher in Home-front command soldiers as compared to infantry soldiers (Infantry – 11.0% vs. Home-front Command - 17.2%; p=0.027). No significant statistical differences in ankle sprain were found when comparing the use of eyeglasses, age, height, weight or BMI

category. A description of the study population characteristics divided by ankle sprain status during a one-year follow-up can be found in Table 4.

Characteristic	Ankle Sprains	No Ankle Sprains	P value
Number (% from total)	352 (14.2)	2,122 (85.8)	
Gender			
Male (% within gender)	220 (13.2)	1,443 (86.8)	p=0.042
Female (% within gender)	132 (16.2)	679 (83.7)	
LESS-RT Score	4 Range: 2-9	3 Range: 1-5	p=0.159
Age (years $\pm$ SD)	19.4 $\pm$ 1.2	19.5 $\pm$ 2.5	p=0.902
Height (cm $\pm$ SD)	170.3 $\pm$ 9.1	171.0 $\pm$ 8.8	p=0.256
Weight (kg $\pm$ SD)	67.8 $\pm$ 10.4	67.7 $\pm$ 10.6	p=0.998
BMI (kg/m² $\pm$ SD)	23.4 $\pm$ 3.2	23.1 $\pm$ 3.0	p=0.485
BMI Category			
<18 (% within category)	4 (5.9)	64 (94.1)	p=0.108
18-25 (% within category)	251 (14.2)	1516 (85.8)	
25-30 (% within category)	64 (13.9)	396 (86.1)	
30-35 (% within category)	12 (23.5)	39 (76.5)	
35< (% within category)	2 (15.4)	11 (84.6)	
Missing	115		
Service Unit			
Infantry (% within unit)	81 (11.0)	655 (89.0)	p=0.027
Special Units (% within unit)	49 (13.7)	308 (86.3)	
Non-infantry (% within unit)	42 (15.1)	235 (84.8)	
Home Front Command (% within unit)	80 (17.2)	385 (82.8)	
Commanders Training (% within unit)	100 (15.7)	539 (84.4)	

Table 4. Characteristics of the study population divided by ankle sprain status during a one-year follow-up.

LESS-RT Score by Ankle Sprain Status:

Mann–Whitney U test was used to compare means of LESS-RT scores between soldiers who sustained ankle sprains and those who did not. The difference in mean LESS-RT score was not significant between these two groups (Ankle sprain - 3 vs. No ankle sprain - 4; $p=0.159$)

ROC Analysis for Ankle Sprains:

ROC analysis for LESS-RT scores as a predictor of ankle sprains in IDF soldiers yielded an AUC of 0.523 (95% CI 0.491-0.556) (Table 5).

	Overuse injuries	Ankle sprain
AUROC*	0.537	0.523
95% CI **	0.514 – 0.560	0.491 – 0.556

Table 5. Receiver operator characteristic analysis derived from LESS-RT scores and overuse injury and ankle sprain occurrence among IDF soldiers.

Discussion:

The purpose of this study was to evaluate the efficiency of the LESS-RT as a predictive tool for lower limb overuse injuries and ankle sprains.

LESS-RT Scores in this Study as Compared to Previous Studies:

We observed a median LESS-RT score of 3 among our study’s population. Median LESS-RT scores were higher (6) in the only previously published study involving the LESS-RT²⁵. This disparity may be explained by the considerable differences in population size (2,474 vs. 43 subjects), fitness levels, medical histories, training experience and prior medical screening (IDF combat soldiers vs. US Military Academy Freshmen).

Additionally, rater proficiency may differ between our study and the above cited study²⁵ , however, previous trials have demonstrated that rater proficiency with regards to the LESS does not necessarily bring about reliable and consistent results^{24,32}.

LESS-RT as a Prediction Test for Overuse Injuries:

The difference in median scores of subjects with overuse injuries was significant when compared with those who did not sustain such injuries (5 vs. 3 ; $p=0.001$). The ROC curve using the LESS-RT as a predictor of overuse injuries yielded an AUC of 0.537 (95% CI 0.514 - 0.560). These results indicates that the LESS-RT test has no predictive value for overuse injuries.

LESS-RT as a Prediction Test for Ankle Sprains:

Median LESS-RT score was not significantly different between soldiers with ankle sprains as compared with soldiers without ankle sprains (Ankle sprain - 3 vs. No ankle sprain - 4; $p=0.159$). Using ROC analysis for LESS-RT and ankle sprains, the AUC was 0.523 (95% CI 0.491-0.556). These results indicates that the LESS-RT has no predictive value for ankle sprains.

Other Salient Findings of this Study:

The incidence of overuse injuries in this study was 59.3% (1,467 out of 2,474 subjects). This rate is substantially higher than reported in previous studies which demonstrated overuse injury rates of 30-40%^{2,3,7,8}, however, this study's population consisted only of soldiers who reported to IPARC who may not necessarily be representative of the entire population of the IDF's combat soldiers. Nevertheless, in our opinion, this result serves as further evidence of the importance of overuse injuries as a significant military public health issue^{1-4,34-6}. Furthermore, these findings emphasize the necessity for the development of centers such as IPARC and efficient predictive tools aimed at screening and reducing injury rates.

Approximately 50% of overuse injuries occurred by the first 2 months of follow-up. This temporal distribution is particularly important in our opinion since it emphasizes that preventive efforts should be mainly implemented during the initial portion of basic combat training in order to maximize efficiency.

The incidence of ankle sprains in this study was 14.2% (352 out of 2,747 subjects), a rate similar to those found in other studies^{34,5}. soldiers serving in special units were 1.58 times (58%) more likely to sustain ankle sprains as compared to infantry soldiers (CI 1.16-2.14; $p=0.004$).

Ankle sprains are considered one of the most common overuse injuries and this finding may indicate that these injuries are indeed correlate with specific conditioning or training regimens encountered during special unit training which are omitted from infantry regimens.

Study Limitations:

1. selection bias - only soldiers that were send by their units to IPASRC were included in this study

2. The study population is homogenous in terms of demographics such as age and biomechanical characteristics, raising the issue of external validity.
3. The raters scoring LESS-RT tests in this study may have been less qualified and Experienced as the raters in other published studies.
4. To the best of our knowledge, only one previous publication has empirically evaluated the LESS-RT and no evidence has been published validating the LESS-RT as a tool for injury prediction. Therefore, we could not compare the results of this study to previously published results.

Conclusion

1. Based on the results of this study, LES-RT has no predictive value for overuse injuries of the lower limb nor for ankle sprains.
2. The high rates of overuse injuries found in this study stress the need for the institution of preventive measures aimed at reducing rates of such injuries.

Declarations

Ethics approval and consent to participate:

This study was approved by the IDF's Institutional Review Board (IRB), (Approval number: 1634-2015). Data analysis was performed using anonymized databases after exclusion of all identifying details.

Consent for publication:

Not Applicable

Availability of data and materials:

The data that support the findings of this study are available from IDF's medical corps informatics branch, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the commander of informatics branch of the IDF's medical corps.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

Dr. Oren Schwartz, Dr. Tomer Talmy and Prof. Israel Dudkiewicz were involved in protocol development, gaining ethical approval, study conduction and data analysis.

Prof. Cara H Olsen was involved in statistics, data analysis and substantially contributed to writing of the first draft of the manuscript.

All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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