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SYSTEMATIC REVIEW

Dynamic Movement Assessment and Functional Movement Screening for injury prediction: a systematic review

Dynamic Movement Assessment e Functional Movement Screen para predição de lesões: uma revisão sistemática

Dynamic Movement Assessment y Functional Movement Screen para la predicción de la lesión: una revisión sistemática

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ABSTRACT | Dynamic Movement Assessment™ (DMA™) and Functional Movement Screening™ (FMS™) are tools to predict the risk of musculoskeletal injuries in individuals who practice physical activities. This systematic review aimed to evaluate the association of DMA™ and FMS™ with the risk of musculoskeletal injuries, in different physical activities, categorizing by analysis. A research without language or time filters was carried out in November 2016 in MEDLINE, Google Scholar, SciELO, SCOPUS, SPORTDiscus, CINAHL and BVS databases using the keywords: "injury prediction", "injury risk", "sensitivity", "specificity", "functional movement screening", and "dynamic movement assessment". Prospective studies that analyzed the association between DMA™ and FMS™ with the risk of musculoskeletal injuries in physical activities were included. The data extracted from the studies were: participant's profile, sample size, injury's classification criteria, follow-up time, and the results presented, subdivided by the type of statistical analysis. The risk of bias was performed with Newcastle-Ottawa Scale for cohort studies. No study with DMA™ was found. A total of 20 FMS™ studies analyzing one or more of the following indicators were included: diagnostic accuracy (PPV, NPV and AUC), odds ratios (OR) or relative risk (RR). FMS™ showed a sensitivity=12 to 99%; specificity=38 to 97%; PPV=25 to 91%; NPV=28 to 85%; AUC=0.42 to 0.68; OR=0.53 to 54.5; and RR=0.16-5.44. The FMS™ has proven to be a predictor of musculoskeletal injuries. However, due to methodological limitations, its indiscriminate usage should be avoided.

Keywords | Cumulative Trauma Disorders; Athletic Injuries; Movement.

RESUMO | A Dynamic Movement Assessment (DMA™) e o Functional Movement Screening (FMS™) são ferramentas utilizadas para classificar o risco de lesões musculoesqueléticas em indivíduos que praticam exercícios físicos. O objetivo da presente revisão sistemática foi avaliar a associação de DMA™ e FMS™ com o risco de lesões musculoesqueléticas em diferentes atividades físicas, categorizando por análise. Uma pesquisa sem filtros de idioma ou de tempo foi realizada em novembro de 2016 nas bases de dados MEDLINE, Google Scholar, SciELO, SCOPUS, SPORTDiscus, CINAHL e BVS, utilizando as palavras-chave: "predição de lesão", "risco de lesão", "sensibilidade", "especificidade", "functional movement screening" e "dynamic movement assessment". Foram incluídos estudos prospectivos que analisaram a associação entre DMA™ e FMS™ com o risco de lesões musculoesqueléticas em atividades físicas. Foram extraídos dos estudos: perfil dos participantes, tamanho da amostra, critérios de classificação da lesão, tempo de seguimento e os resultados apresentados, subdivididos pelo tipo de análise estatística. O risco de

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viés foi realizado com a Escala Newcastle-Ottawa para estudos de coorte. Não foi encontrado nenhum estudo sobre a DMA™. Foram incluídos 20 estudos, que analisaram um ou mais dos seguintes indicadores: acurácia diagnóstica (VPP, VPN e AUC), razão de chances (OR) ou risco relativo (RR). O FMS™ apresentou sensibilidade=12-99%; especificidade=38-97%; VPP=25-91%; VPN=28-85%; AUC=0,42-0,68; OR=0.53-54.5; e RR=0,16-5,44. O FMS™ apresentou-se como um método preditor de lesões musculoesqueléticas. Entretanto, devido às limitações metodológicas dos estudos, seu uso indiscriminado deve ser evitado.

Descritores | Transtornos Traumáticos Cumulativos; Traumatismos em Atletas; Movimento.

RESUMEN | Evaluación Dinámica del Movimiento™ (DMA™) y Detección del Movimiento Funcional ™ (FMS™) son herramientas para predecir el riesgo de lesiones musculoesqueléticas en individuos que practican actividades físicas. Esta revisión sistemática tuvo como objetivo evaluar la asociación de DMA™ y FMS™ con el riesgo de lesiones musculoesqueléticas en diferentes actividades físicas y categorizarlas por análisis. En noviembre de 2016 se llevó a cabo una investigación sin filtros de idioma o de tiempo en las bases de datos MEDLINE, Google Scholar, SciELO, SCOPUS, SPORTDiscus, CINAHL y BVS, utilizando las palabras clave: predicción de lesiones, riesgo de lesiones, sensibilidad, especificidad, detección del movimiento funcional y evaluación dinámica de movimientos. Se incluyeron estudios prospectivos que analizaron la asociación entre DMA™ y FMS™ con el riesgo de lesiones musculoesqueléticas en actividades físicas. Los datos extraídos de los estudios fueron: perfil del participante, tamaño de la muestra, criterios de clasificación de la lesión, tiempo de seguimiento y los resultados presentados, subdivididos por el tipo de análisis estadístico. El riesgo de sesgo se realizó con la Escala Newcastle-Ottawa para estudios de cohorte. No se encontró ningún estudio con DMA™. Se incluyeron un total de 20 estudios FMS™ que analizaron uno o más de los siguientes indicadores: precisión diagnóstica (VPP, VPN y ABC), odds ratios (OR) o riesgo relativo (RR). FMS™ mostró una sensibilidad = del 12 al 99%; especificidad = del 38 al 97%; VPP = del 25 al 91%; VPN = del 28 al 85%; ABC = 0,42 a 0,68; OR = 0,53 a 54,5; y RR = 0,16-5,44. El FMS™ ha demostrado ser un predictor de lesiones musculoesqueléticas. Sin embargo, debido a limitaciones metodológicas, se debe evitar su uso indiscriminado.

Palabras clave | Transtornos de Traumas Acumulados; Traumatismos en Atletas; Movimiento.

INTRODUCTION

Musculoskeletal injuries are one of the main causes of morbidity in individuals who practice physical exercises[1–3]. Thus, several screening methods have been developed aiming at classifying the risk of injury. In this context, functional tests based on subjective evaluations have been increasingly performed[4] to verify the movement patterns and dysfunctions associated with injuries of the trunk and lower limbs[5,6]. The subjectivity of these evaluations limits their reliability[7]. However, they are a low-cost alternative in large-scale evaluations and in case of absence of gold standards[8].

To establish a risk classification tool for musculoskeletal injuries, Cook et al.[9] developed the Functional Movement Screening™ (FMS™). This method classifies the risk of injury in the presence of abnormal movement patterns by performing seven tests/movements[9,10]. Each test can be evaluated from zero to three points and assess the interactions of kinetic chain mobility and stability needed to perform fundamental movement patterns. The score ranges from 0 to 21 points. Initial studies have shown that soccer players with scores of 14 or less in the total score have a higher risk of injury[11]. Thus, this method has been used in preseasons of several modalities of sports to modify movement patterns that can cause injuries[10,12]. However, the efficacy of FMS ™ to predict injuries is controversial among authors[13–15], likely justified by the different demands among sports[13].

Years later, Nessler & Dunn developed the Dynamic Movement Assessment™ (DMA™)[5]. It consists of filming the individual performing six functional tests. The video analysis is performed using a two-dimensional (2D) biomechanical analysis software. The 2D evaluation allows visualizing movement dysfunctions in the frontal plane, such as dynamic valgus[8]. Each of the six DMA™ tests is rated with a score ranging from zero (if the pain is related to the test) to three points. Each test has a major deviation and secondary deviations, which are observed. Failing to perform the test, the presence of three minor deviations, or a major deviation of greater magnitude characterizes a one-point score. The presence of two secondary

deviations or a major deviation with intermediate magnitude promotes two points. Finally, individuals who perform the test without clinically important deviations are classified with three points[5].

Due to the low cost and easy feasibility of the FMS™ and DMA™, their use to evaluate individuals who practice physical exercises in several groups is attractive. The main difference between the two methods is that DMA™ is based on functional tests with unilateral support (squatting and vertical jump), common in the sport gesture of several modalities[5].

The fact that the incidence of injuries in people who practice sports[16,17] or occupational physical exercises[1,18,19] is high justifies this review. Getting to know a low-cost and easy-to-use test that measures fundamental movement dysfunctions, potentially predicting athletic injuries, may allow the development of preventive strategies that avoid the removal of functions involving physical exercises. Moreover, previous reviews evaluated only the diagnostic accuracy indicators of prospective studies of FMS™. Thus, the purpose of this systematic review is to evaluate the association of DMA™ and FMS™ with the risk of musculoskeletal injuries.

METHODOLOGY

This systematic review was registered in PROSPERO (CRD42017068014) and drafted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement[20].

Inclusion criteria

The studies included in this systematic review were prospective studies that used the FMS™ or DMA™ to classify the risk of musculoskeletal injuries in physical exercise practitioners of both sexes and without age limits. More detailed information about FMS™ and DMA™ are found in the studies of Cook et al., and Nessler & Dunn, respectively[5,9].

Search strategy

A search was conducted in November 2016 in US National Library of Medicine (MEDLINE), Scientific Electronic Library Online (SciELO), Google Scholar, Virtual Health Library (VHL), CINAHL (EBSCOhost), SPORTDiscus and SCOPUS. The following keywords were used as descriptors of the Medical Subject Headings (MeSH): injury prediction, injury risk, functional movement screening, and dynamic movement assessment. The sentences used in this research were done with the Boolean operators AND (between the descriptors) and OR (between descriptor's synonyms). No date limits or language filters were applied.

Data collection process

The following data were extracted from the selected studies: profile of the participants, sample size, classification of musculoskeletal injuries, follow-up time and type of statistical analysis performed with its results.

Bias risk analysis

For bias risk analysis, the Newcastle-Ottawa scale was used[21]. The domains considered in this scale are: (1) selection (representativeness of the exposed cohort, selection of the unexposed cohort, evaluation of the exposure and confirmation that the result of interest was not present at the beginning of the study, (2) comparison of the cohort based on the study design or analysis (if results were adjusted for the main confounding factors and other variables) and (3) outcome (outcome assessment, sufficient follow-up time, and adequacy of cohort follow-up). Studies with less than five stars were classified as a "high risk of bias." In addition, studies were considered to have a "risk of uncertain bias" as they did not score in the "comparison" domain. The bias risk analysis was performed by only one evaluator.

RESULTS

Flow diagram

The total of studies per database and flow diagram of the studies are in Figure 1. Seven studies were manually located. None of the studies investigated the DMA™. Characteristics of the studies included are in Table 1. Statistical analysis and its result are shown in Table 2, and bias risk analysis are exposed in Table 3.

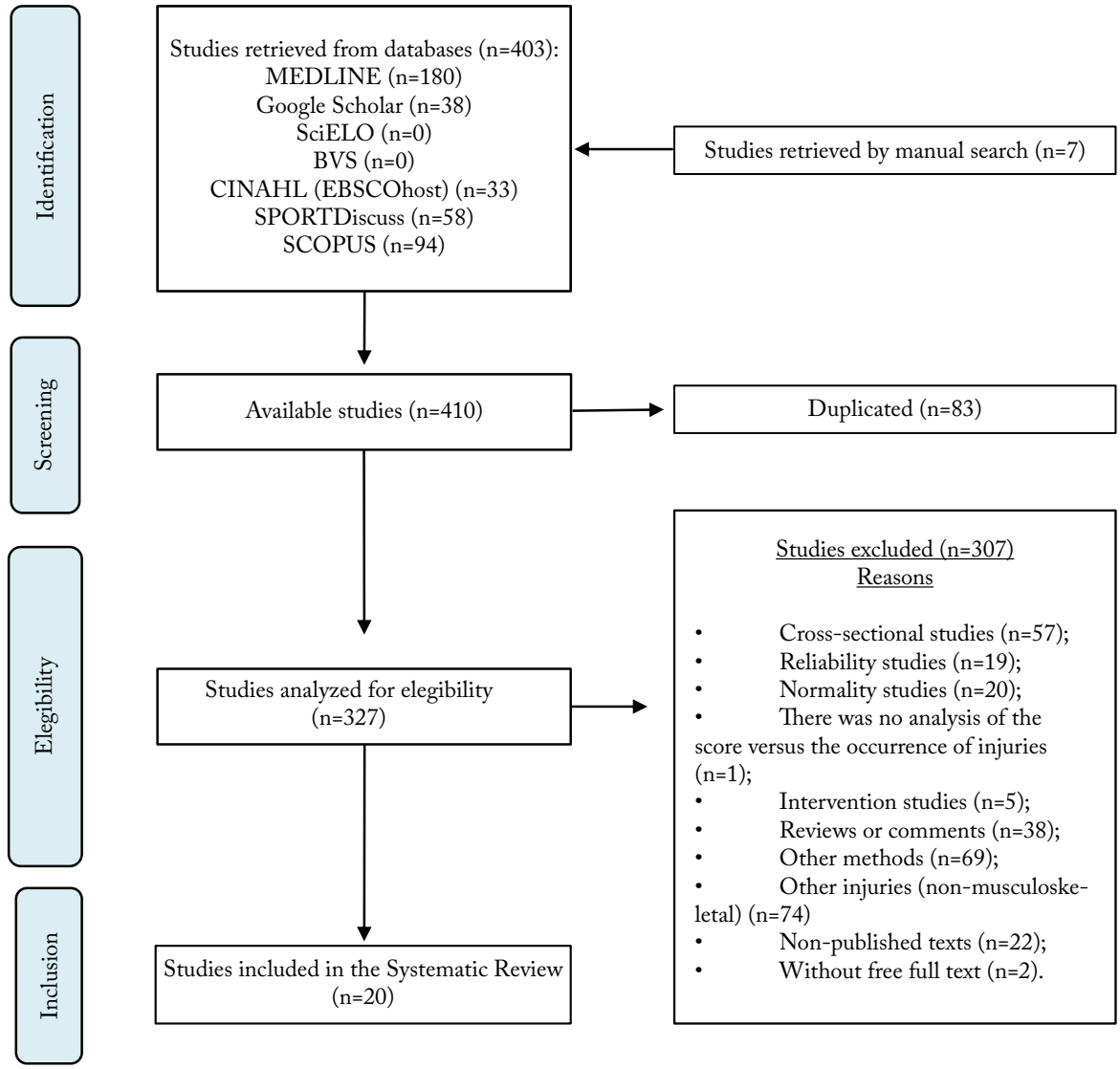

Figure 1. Flow diagram

Table 1. Characteristic of included studies

Study	Participants	Sample	Injury's classification criteria	Follow-up time
Bushman et al., 2015[22]	Military personnel	n=2476 soldiers; Age=18 – 57 years old.	I	6 months
Lisman et al., 2013[23]	Military personnel	n=447 (ST) and n=427 (LT) marine officer's students; Age=22.4±2.7 years old.	I	6 (n=427) or 10 weeks (n=447), according with course (ST or LT).
Kodesh et al., 2015[24]	Military personnel	n=158 female soldiers from the Combat Fitness Instructor Course (CFIC) – Israel Defense Forces (IDF); Age=19.0 (18.1 – 20.2) years old.	I	Three months
Butler et al., 2013[25]	Military personnel	n=108 firefighter training course students; Age=NR.	III*	4 months
McGill et al., 2015[26]	Military personnel	n=53 men, elite police department; Age=37.9±5 years old.	I, II	5 years
O'Connor et al., 2011[27]	Military personnel	n=874 marine officer's students; Age=18 – 30 years old.	I, III**	6 (n=427) or 10 weeks (n=447), according with course (ST or LT).

(continues)

Table 1. Continuation

Study	Participants	Sample	Injury's classification criteria	Follow-up time
Warren et al., 2015[28]	Athletes	n=167 college athletes; Age=18 – 24 years old.	I	One Season
Kiesel et al., 2007[11]	Athletes	n=46 football players; Age=NR.	III*	4,5 months
Tee et al., 2016[29]	Athletes	n=62 rugby players; Age=NR.	III*	6 months
Azzam et al., 2015[30]	Athletes	n=34 basketball players; Age=NR.	III#	One season
Clay et al., 2016[31]	Athletes	n=45 Division I female collegiate rowers; Age=at least 18 years of age;	III	One season
Bardenett et al., 2015[32]	Athletes	n=185 (97 women, 88 men) high school athletes – several modalities; Age=13 – 18 years old.	II, III	One-quarter (autumn)
Hammes et al., 2016[33]	Athletes	n=238 football players >32 years old; Age=44±7 years old.	I, III	9 months
Kiesel et al., 2014[34]	Athletes	n=238 football players; Age=NR.	I, III	One preseason
Chorba et al., 2010[35]	Athletes	n=38 collegiate athletes, women – several modalities; Age=18 – 26 years old.	I, II	One season
Dossa et al., 2014[36]	Athletes	n=20 hockey players; Age=16 – 20 years old.	II, III	One season (2013-2014)
Weise et al., 2014[37]	Athletes	N=144 collegiate athletes – football; Age=18.9±1.3 years old.	I, II, III	One season
Garrison et al., 2015[38]	Athletes	n=168 collegiate athletes – several modalities Age=17 – 22 years old.	I, II, III	One season
Mokha et al, 2016[39]	Athletes	n=84 (20 men) – several modalities; Age=20.4±1.3 years old (men) and 19.1±1.2 (women).	I, II, III	One season
Martin et al., 2016[40]	Athletes	n=27 adolescent Cricket Pace Bowlers ; Age=13 – 18 years old.	I, II, III	One season

N=sample size; NR=Not reported; TI=traumatic injuries; NTI=nontraumatic injuries; AI=all injuries; ICD=International Code of Diseases; ST=short term course; LT=long term course. Criteria used to define the injuries: I) the diagnosis of the injuries was performed by a healthcare professional; II) The registered injuries were related to the training or competition; and III) Only the musculoskeletal injuries with time-loss longer than 24 hours were considered lesions; III*=time-loss longer than 3 weeks; III**=a severe injury promotes withdrawal from the training program; III#=time-loss longer than 7 days.

Table 2. Statistical analysis

Statistical analysis	Author	Results
Diagnostic accuracy	Bardenett et al., 2015[32]	AUC=0.49; IG versus NIG (P=0.95); s=0.56; e=0,38, +LR=0.91; -LR=1.14
	Bushman et al., 2015[22]	FMS (cutoff=14): NTI: s=37%; e=81%; PPV=43%; NPV=77% AUC: 61%; TI: s=28%; e=77%; PPV =19%; NPV=85% AUC: 54%; AI: s=33%; e=82% VPP=52%; VPN=68% AUC: 60%
	Garrison et al., 2015[38]	FMS (cutoff=14): s=0.67, e= 0.73, +LR=2.51; -LR=0.45; FMS (cutoff=14) + past injuries: s= 0.65, e=0.89, +LR=5.88; -LR=0.39
	Hammes et al., 2016[33]	FMS (cutoff=14): AUC (any injury)=0.56; CI 95%=0.47-0.64; P=0.17; AUC (NTI)=0.55; CI 95%=0.46-0.64, P=0.30)
	Kiesel et al., 2007[11]	FMS (cutoff=14): s=0.54 (CI 95%=0.34-0.68); e=0.91 (CI 95%=0.83-0.96), +LR=5.92 (CI 95%=1.97-18.37), -LR=0.51 (CI 95%=0.34-0.79)
	Kiesel et al., 2014[34]	FMS (cutoff=14): s=0.26 (CI 95%=0.18-0.36), e= 0.87 (CI 95%=0.84-0.90; FMS (cutoff=14)+asymmetry: e=0.87 (CI 95% 0.84-0.90)
	Chorba et al., 2010[35]	FMS (cutoff=14): s=0.579 (CI 95%=0.335-0.798); e=0.737 (CI 95%=0.488-0.909); +LR=2.200 (CI 95%=0.945-5.119)
	Mokha et al, 2016[39]	FMS (cutoff=14): s=26,3%; e=58.7%
	Dossa et al., 2014[36]	s=0.5 (CI 95%=0.189-0.811); e=0.7 (CI 95%=0.348-0.930); +LR=1.67 (CI 95%=0.54-5.17); -LR=0.71 (CI 95%=0.34-1.50); PPV=62.50% (CI 95%=0.25-0.91); NPV=58.33% (CI 95%=0.28-0.85)
	McGill et al., 2015[26]	s=0.28 (low back pain) e 0.42 (AI); e=0.76 (low back pain) and 0.47 (AI); P=NR
	O'Connor et al., 2011[27]	s=0.452 (AI), 0.12 (severe injury) and 0.13 (NTI). e=0.782 (AI), 0.939 (severe injury) and 0.901 (NTI). AUC=0.58 (AI), 0.53 (severe injury) and 0.52 (NTI).

(continues)

Table 2. Continuation

Statistical analysis	Author	Results
Diagnostic accuracy	Weise et al., 2014[37]	AUC=0.491 (P=0,854), s=0.495;1- e=0.429, +LR=1.154 (P=0.819); UL injuries (FMS cutoff =17): AUC =0.483 (P=0.769); s=0.500; 1-e=0.464; +LR =1.078 (P=0.765) LL injuries (FMS cutoff =17): AUC=0.486 (p=0.766); s=0.480; 1-e=0.464; +LR =1.035(P=0.762) NTI: AUC=0.490 (P=0.846); s=0.232; 1-e=0.216; RVP=1.075(P=0.843); Injuries with time-loss > 10 days: AUC=0.422(P=0.194), s=0.996; e=0.974; +LR=0.992(P=0.187)
	Tee et al., 2016[29]	s=0.83 (CI 95%=0.52-0.98); e=0.46 (CI 95%=0.35-0.48); AUC=0.68 and P=0.049
	Warren et al., 2015[28]	s=0.54; e=0.46; AUC=0.48
	Kodesh et al., 2015[24]	s=0.42; e=0.63; AUC=0.51
Odds Ratios	Bushman et al., 2015[22]	FMS (cutoff=14): OR=1.96 (P=0.01)
	Garrison et al., 2015[38]	FMS (cutoff=14): OR=5.71; CI 95%=2.73-11.51
	Kiesel et al., 2007[11]	FMS (cutoff=14): OR=11.67 (CI 95%=2.47-54.52)
	Chorba et al., 2010[35]	FMS (cutoff=14): OR=3.850 (CI 95%=0.980-15.13)
	Mokha et al, 2016[39]	FMS (cutoff=14): OR=2.07 (P=0.15). FMS (cutoff=14)+asymmetry: OR=5.27 (CI 95%=1.93-14.40; P=0.001)
	O'Connor et al., 2011[27]	OR: AI (OR=2.0; (CI 95%=1.3-3.1, P=0.002), NTI (OR=1.4; CI 95%=0.71-2.6, P=0.35); severe injuries (OR=2.0; CI 95%=1.0-4.1; P=0.05)
	Weise et al., 2014[37]	FMS (cutoff=17): AI-OR =1.425 (P=0.392); CI 95%=NR; UL injuries-OR=1.134 (P=0.793); LL injuries-OR=1.113 (P=0.789); FMS (cutoff=18): NTI-OR=0.949 (P=0.926); FMS (cutoff=12): Injuries with "time-loss" >10 days: OR=2.154 (P=0.380).
	Lisman et al., 2013[23]	ST/FMS (cutoff=14): AI-OR=2.04 (CI 95%=1.32-3.15) and P=0.001; NTI-OR=1.34 (CI 95%=0.70-2.56) and P=0.382; TI–OR=1.92 (CI 95%=1.21-3.02) and P=0.005; LT/FMS (cutoff=14): AI-OR=2.10 (CI 95% =1.34-3.29) and P=0.001; TI-OR=1.80 (CI 95%=1.12-2.89) and P=0.015; NTI: NR.
	Butler et al., 2013[25]	OR: 1.21 (CI 95%=1.01-1.42)
	Tee et al., 2016[29]	OR=4,3 (CI 95%=0.9-21.0)
	Warren et al., 2015[28]	OR=1.01 (CI 95%=0.53-1.91)
	Kodesh et al., 2015[41]	OR=0.98 (CI 95%=0.87-1.10)
Relative Risk	Bushman et al., 2015[22]	FMS (cutoff=14): RR=1.86 (NTI) and RR=1.49 (AI) – P=0.01)
	Kiesel et al., 2014[34]	FMS (cutoff=14): RR=1.87 (CI 95%=1.20-2.96)
	Mokha et al, 2016[39]	FMS (cutoff=14): RR=2.73 (CI 95% =1.36 – 5.44; P=0.001); FMS (cutoff=18): RR=0.56 (CI 95%=0.34-0.93)
	O'Connor et al., 2011[27]	ST – FMS (cutoff=14): RR (AI)= 1.91 (CI 95%=1.21-3.01; P<0.01); LT – FMS (cutoff=14): RR (AI)=1.65 (CI 95%=1.05-2.59; p=0.03); ST+LT: RR (AI)=1.5 (P=0.003)
	Azzam et al., 2015[30]	RR=0.86 (CI 95%=0.42-1.76)
	Martin et al., 2016[40]	RR=0.59 (CI 95%=0.16-2.20)
	Kodesh et al., 2015[41]	RR*=1.49 (CI 95%=0.998-2.23)

P=P-value; NR=Not reported; IG=injured group; NIG=non-injured group; CI 95%=confidence interval to 95%; s=sensibility; e=specificity; PPV=positive predictive value; NPV=negative predictive value; ROC: Receiver Operating Characteristic; AUC=area under the "receive operator curve"; TI=traumatic injuries; NTI=nontraumatic injuries; AI=all injuries; FMS=Functional Movement Screen; +LR=Positive likelihood ratio; -LR=negative likelihood ratio; ICD=International Code of Diseases; UL=upper limbs; LL=lower limbs; ST=short term course; LT=long term course; OR=odds ratios; RR=relative risk.

Table 3. Bias risk of studies that evaluated the association of FMS™ with the risk of musculoskeletal injuries with Newclastle-Ottawa Scale (NOS)

Domain/study	Selection	Comparability	Outcome	Score	Risk
Bushman et al.[22]	***	**	*	******	Low
Garrison et al.[38]	**	*	*	****	High
Kiesel et al.[11]	**	-	*	***	High
Lisman et al.[23]	****	**	*	*******	Low
Butler et al.[25]	****	-	**	******	Uncertain
Chorba et al.[35]	***	*	-	****	High
Mokha et al.[39]	***	-	-	***	High
O'Connor et al.[27]	****	**	*	*******	Low
Weise et al.[37]	***	-	*	****	High

(continues)

Table 3. Continuation

Domain/study	Selection	Comparability	Outcome	Score	Risk
Kiesel et al.[34]	**	-	-	**	High
Bardenett et al.[32]	***	-	**	*****	Uncertain
Dossa et al.[36]	**	-	*	***	High
Hammes et al.[33]	***	**	*	******	Low
McGuill et al.[26]	**	-	*	***	High
Tee et al.[29]	***	-	*	****	High
Azzam et al.[30]	**	-	**	****	High
Martin et al.[40]	***	-	**	*****	Uncertain
Warren et al.[28]	***	-	**	*****	Uncertain
Kodesh et al.[24]	***	-	*	****	High
Clay et al.[31]	***	-	*	****	High

Domains of Newcastle-Ottawa Scale (NOS): Selection (representativeness of the exposed cohort; selection of the nonexposed cohort; ascertainment of exposure and demonstration that the outcome of interest was not present at the beginning of the study); Comparability (principal factor and any additional factor); and Outcome (assessment of outcome; if the follow-up was long enough for producing outcomes; and adequacy of follow-up of cohorts).

DISCUSSION

This review aimed to evaluate the association between FMS™ and DMA™ with the risk of musculoskeletal injuries. No studies with DMA™ were found, probably due to its recent development[5]. Based on the statistical analysis of most studies evaluated, FMS™ is associated with the risk of musculoskeletal injuries. Considering the cohort studies by Bushman et al.[22] and O'Connor et al.[27], which had the lowest risk of bias, this association is strengthened (Table 3).

According to Table 2, the FMS™ showed sensitivity values ranging from 26 to 68%; specificity from 38 to 96%; PPV from 19 to 91%; NPV from 28 to 85%; and AUC from 0.42 to 0.68 (Table 2). Therefore, it is noticeable that the indicators of diagnostic accuracy are divergent between the 12 studies. OR values also ranged from 0.53 to 11.67, which corresponds, according to the literature, to absent and large effect sizes, respectively[41]. Only seven studies calculated the RR[20, 27, 34, 35, 40, 42, 43], whose results were RR=1.86 (overuse injuries)[22], RR=1.49 (traumatic injuries)[22]; and RR=-0.5[40] to 2.73[39] (any injury). Thus, a low score in FMS™ is associated with higher injury risk, although this result is limited by the number of studies that calculate the RR and the high risk of bias in two of those studies[27,34].

Considering the results of the studies with low risk of bias (Table 3), it is verified that FMS has a low sensitivity[20,22,40], a good specificity[20,33], and AUC values slightly above chance[20,22]. Three out of the four studies with low risk of bias used samples composed of soldiers[20,33,40]. These studies showed a higher score in the "selection" domain. This observation is a consequence of a greater representativeness of the samples in military courses, an adequate selection of the unexposed cohort (which is part of the same population) and the monitoring of the exhibition (based on the analysis of base records, such as military base records). At the same time, military groups are generally more homogeneous regarding various characteristics (age, level of fitness, volume of physical exercise, routine, etc.). Only six studies analyzed the influence of potential confounders[20–22,33,40,41]. Thus, all other studies have a "high" or "uncertain" risk of bias, once the influence of other risk factors on the result obtained was not reported. Most of the samples used had little representativeness, especially in studies with athletes. In addition, in many cases, attrition rates were neither quoted nor justified. In some cases, the absence of cases was not confirmed at the beginning of the studies, and it was not clear whether there was blinding of the participant and the professional responsible for the follow-up, which limits the interpretation of the results.

All the studies included in this systematic review had the same prospective design, in which the association between the score of FMS™ and the risk of injury were evaluated. Among 20 studies, 15 performed the diagnostic accuracy analysis, 12 calculated the OR and 7 the RR. The large variation between the results might have relation to several factors. First, samples consisted of athletes from different modalities or soldiers. In addition, the age of the individuals differed from one study to the other. Probably, FMS™ is not an appropriate assessment tool for every physical exercise practitioner. Second, the

rating of injuries does not follow the same criteria in all studies. Some authors used the definition proposed by Hägglund et al.[42], which defines a musculoskeletal injury when three criteria are related to injuries: association with athletic participation; necessity for health care; and time-loss with restrict participation for at least 24 hours. However, some authors included only severe injuries (with time-loss larger than three weeks)[11] or any injury[19,20,22,24,27,40,41]. Third, statistical analysis based on indicators of diagnostic accuracy or simple calculation of OR limits the interpretation[41]. Diagnostic accuracy indicators are found in studies evaluating the validity of an index test compared with a reference standard[43,44]. In injury prediction studies, considering the occurrence of injuries as a reference pattern may limit the interpretation of the results, since a high-risk individual may not suffer an injury, especially if he/she is not exposed to the risk factor. The use of OR evaluates the chance of a high-risk individual to develop injuries. However, it does not consider the injury incidence[41]. Therefore, the most appropriate calculation is the relative risk.

This systematic review was the first to evaluate the association of FMS™ and DMA™, categorizing by type of statistical analysis performed. However, the small number of studies evaluating the RR of FMS™ and the absence of studies with DMA™ were limitations. In future studies, the control of some biases is recommended. Most of the studies did not perform pairing of variables such as gender, age and other variables of interest, such as sport modalities[45]. In this case, we suggest using logistic regression analysis. Another critical point was the lack of confirmation of case of absences in the baseline, as well the non-blinding of the evaluators responsible for monitoring the sample. In theory, they should not know whether the participant belonged to the group exposed to the risk factor. Finally, the development of studies about the association of DMA™ with the risk of musculoskeletal injuries is suggested, since no studies with this method were found, which uses movements present in several sport gestures with two-dimensional analysis[5].

CONCLUSION

From the studies of this systematic review, the conclusion was that movement dysfunction, evaluated by FMS™, may be associated with the risk of injury in people who practice physical exercises. No studies evaluating the association between the DMA™ score and the risk of injury were found. It is recommended that future studies carry out greater control of selection, comparison and outcome biases, and perform a meta-analysis.

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