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Limited diagnostic value of questionnaire-based pre-participation screening algorithms: a "risk-exposed" approach to sports activity

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Abstract

Background: Several pre-participation screening algorithms (PPSAs) have been proposed to assess sports eligibility in different populations. They are usually based on self-administered questionnaires, without further medical assessment if no risk factors are documented. The Med-Ex "Formula Benessere" worksite program includes a complete cardiovascular (CV) screening for all participants. The purpose of this study was to assess PPSAs accuracy in detecting medical and/or CV abnormalities in the general population, comparing the results with the date derived from Med-Ex program.
Methods: The Med-Ex medical evaluation, consisting of medical history, physical examination (including body composition), resting electrocardiogram (ECG) and exercise stress test in 464 male subjects (38.4 aged) was analyzed and matched to several PPSAs – Physical Activity Readiness Questionnaire (PAR-Q) (2002–2020), American Heart Association (AHA)/American College of Sport Medicine (ACSM) (1998–2009–2014–2015), European Association of Cardiovascular Prevention and Rehabilitation (EACPR) (2011) – retrospectively simulated.
Results: Five-hundred and 67 abnormalities were detected though Med-Ex medical evaluation, and one-fourth (24%) would have been undetected applying PPSA alone. In particular 28% of high blood pressure, 21% of impaired fasting glycaemia, 21% of high Body Mass Index (BMI) values and 19% of ECG abnormalities would have been missed, on average, by all PPSAs.
Conclusions: The simulation analysis model performed in this study allowed to highlight the limits of PPSAs in granting sport eligibility, compared to a medical-guided CV screening. These findings emphasize the importance of a more balanced approach to pre-participation screening that includes a thorough evaluation of the cost/benefit ratio.

Keywords: cardiovascular prevention; pre-participation screening; questionnaires; sport eligibility.

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Introduction

Sudden cardiac death (SCD) associated with sport activity is a rare but devastating event [1, 2]. Although regular physical activity (PA) plays a protective role in this respect [3, 4], it is well known that risk of sudden cardiac death can increase during vigorous exercise [2, 5]. As a result, there is a growing interest in individuals for whom appropriate sports restriction can minimize the risk of SCD [6].

Over the last years, national and international societies have proposed several pre-participation screening algorithms (PPSAs) to identify subjects with an increased risk of adverse effects related to PA. A significant debate arose among physicians about the efficacy, the impact of false-positive results and cost-effectiveness of routine pre participation cardiovascular evaluation of athletes [7, 8]. Some algorithms have been designed for young athletes and professional athletes [9], while few algorithms pointed to define procedures in leisure athletes and in general population [10]. The cardiovascular pre-participation screening in young competitive athletes has gained more attention [11, 12] during last years and it is strictly regulated by national rules in some countries. Nevertheless, the screening of older adults before they engage in PA seems a logical practice for disease prevention, but only a small percentage of them undergo pre-participation screening (24.6–51.5%) [13]. Considering the growing popularity of endurance sport events, such as marathons, involving many adults (often with low fitness levels and coexisting cardiovascular risk factors [13, 14]), CV screening should be mostly implemented in these adult population to limit the risk of SCD during sports.

Moreover, the PPSAs adopted in adult population are usually based on self-administered questionnaires, without further medical assessment, if no risk factors are documented. Even if this strategy admit to easily screen a large percentage of subjects and it is cheap, it should be taken into account that different PPSAs have different specificity and sensitivity, being less accurate than medical assessment [15].

The Med-Ex "Formula Benessere" corporate wellness program [16–19] includes a complete cardiovascular (CV) screening for all participants, independently from the age and level of PA performed, and its effectiveness has been already proved [16, 18].

The purpose of this study is to compare the data came out from Med-Ex Program with the indication derived from PPSAs, assessing their accuracy in detecting medical and/ or CV abnormalities in the general population, with the aim of minimizing the CV risks related to sports activity.

Materials and methods

Between January and December 2021, a corporate wellness program was conducted in an Italian elite car company by Med-Ex s.r.l. Med-Ex is a medical society aimed to conduct preventive corporate wellness programs. The corporate wellness program was organized according to the structure of previous similar activities conducted by Med-Ex s.r.l. in other companies during the last decades and with clinically relevant proved effects on cardiovascular and metabolic outcomes [16, 18, 20]. Participation at the program was completely free for employees. Each subject was assessed by medical doctors and allied professionals. Several medical procedures were completed: medical history collection, general and cardiovascular physical examination, body composition, 12-leads electrocardiogram (ECG) at rest and Exercise Stress Test (EST). Before the visit, each patient signs an informed consent accepting medical procedures and data collection by Med-Ex. Moreover, the data collection form specifies that data should be used for scientific purposes, in aggregate form and maintaining the privacy of each specific subject. Med-Ex treats these data according to privacy rules and protection. Personal and medical patients' data were collected through a medical database. To the purpose of the present study, data were retrieved through the database by an Author with the right to access to the data (AB). Sensible data were concealed, and each record was numbered and was anonymized.

After the end of the project, the complete database was used to retrospectively simulate several Pre-Participation Screening Algorithms (PPSAs) in order to verify the selective ability of each algorithm to intercept the same medical abnormalities, identified by the Med-Ex medical evaluation. In this way, we wanted to verify whether individuals, considered eligible for PA according to each PPSA (without previous medical screening), were actually carriers of silent pathological conditions.

Each algorithm clearly defines the characteristics of the subjects eligible for sport activity without any previous medical consultation ("apparently healthy") and distinguishes them from subjects with higher risk who need medical evaluation to grant sport eligibility. The used criteria for simulation procedure are reported in Table 1. Subjects defined as requiring medical consultation by PPSAs were out of the scope of the present paper. On the other hand, eventual hidden pathological conditions were investigated in subjects considered eligible for sport activity without medical evaluation ("apparently healthy") using medical data recorded by Med-Ex program.

According to data recorded in the database, it was possible to simulate the following PPSAs: American College of Sport Medicine (ACSM) v.1998 [21], ACSM v.2014 [22], ACSM v.2015 [23], European Association of Cardiovascular Prevention and Rehabilitation (EACPR) v.2011 [24]. Each PPSA included a first-step of screening based on self-administered questionnaires: the American Heart Association (AHA) (v. 1998 [21]) (v. 2009 – [25]) and the Physical Activity Readiness Questionnaire (PAR-Q) (v. 2002 – [26]) (v. 2020 – [27]). While the PPSAs proposed by ACSM admitted both questionnaires but clearly advice to use the AHA [22], the PPSA proposed by EACPR [24] omitted to report a clear distinction between these two questionnaires and therefore both of them were used in the simulation. Moreover, the PAR-Q questionnaires are often adopted as standalone methods [28]. Therefore, combining versions of PPSAs and version of questionnaires, according to chronological rules of publication, the following simulations were possible:

- ACSM (v.1998) with AHA (v.1998)
- ACSM (v.1998) with AHA (v.2009)
- ACSM (v.2014) with AHA (v.2009)
- ACSM (v.2015)
- EACPR (v.2011) with AHA (v.1998)
- EACPR (v.2011) with PAR-Q (v.2002)
- PAR-Q (v.2002)
- PAR-Q (v.2020)

The simulation was conducted by two independent medical doctors (S.P and F.S.), not involved in data acquisition during the project. Disagreements were discussed and a final decision for each patient was reached through discussion with a third senior author (A.B.). If data were absent or insufficient, patient was contacted for further information. In some cases, detailed data were not retrieved based on database analysis and on patient's consultation. In these cases, patients were excluded from the final analysis.

Results

Out of 590 male employees enrolled for the present study, 126 have been excluded from the analysis due to the lack of

Table 1: PPSAs definitions for sport eligibility without medical evaluation and simulation criteria adopted in the study based on Med-Ex database.

Algorithm	Version	Questionnaire	PPSAs' definition of subjects eligible for sport activity without medical evaluation	Subjects were defined eligible for sport activity without medical consultation (according to PPSAs' definition) if data in Med-Ex database allow to …
ACSM	1998	AHA v.1998	"Apparently healthy persons of all ages and asymptomatic persons at increased risk (classes A-1 A-2 A-3) may participate in moderate intensity exercise without first undergoing a medical examination or a medically supervised, symptom-limited exercise test"	- Answer "NO" regard items of "history" section of AHA 1998 - Answer "NO" regard items of "symptoms" section of AHA 1998 - Answer "NO" regard items of "other health issue" section of AHA 1998 - Answer "NO" regard items of "CV risk factor" section of AHA 1998
ACSM	1998	AHA v.2009	"Apparently healthy persons of all ages and asymptomatic persons at increased risk (classes A-1 A-2 A-3) may participate in moderate intensity exercise without first undergoing a medical examination or a medically supervised, symptom-limited exercise test"	- Answer "NO" regard items of "history" section of AHA 2009 - Answer "NO" regard items of "symptoms" section of AHA 2009 - Answer "NO" regard items of "other health issue" section of AHA 2009 - Answer "NO" regard items of "CV risk factors" section of AHA 2009
ACSM	2014	AHA v.2009	Subjects at low risk (asymptomatic with <2 cardiovascular risk factors) could undergo a moderate and vigorous exercise without any previous medical examination, exercise test and medical supervision of exercise test	- Answer "NO" regard items of "history" section of AHA 2009 - Answer "NO" regard items of "symptoms" section of AHA 2009 - Answer "NO" regard items of "other health issue" section of AHA 2009 - Answer "NO" regard items of "CV risk factors" section of AHA 2009 - Answer "NO" regard items of "known CV, pulmonary, metabolic disease" section of ACSM 2014 - Answer "NO" regard items of "major symptoms suggestive of CV, pulmonary, metabolic disease" section of ACSM 2014 - Identify "less than two" regard "number of CV risk factors" section of ACSM 2014
ACSM	2015		"Physically inactive but otherwise healthy asymptomatic persons may begin light- to moderate-intensity exercise without medical clearance and, in the absence of symptoms, progress gradually in intensity as recommended by current ACSM exercise prescription guidelines"	- Answer "NO" regard items of "participate in regular exercise" section of ACSM 2015 - Answer "NO" regard items of "CV, metabolic or renal disease" section of ACSM 2015 - Answer "NO" regard items of "signs or symptoms suggestive of CV, metabolic or renal disease" section of ACSM 2015
EACPR	2011	AHA v.1998	"Middle-aged/older sedentary individuals who wish to engage in low-intensity PA (<3 METS) are considered eligible without further evaluation, if the assessment of risk using validated questionnaires is considered negative"	- Defined ad age ≥35 years - Answer "NO" regard items of "history" section of AHA 2009 - Answer "NO" regard items of "symptoms" section of AHA 2009 - Answer "NO" regard items of "other health issue" section of AHA 2009 - Answer "NO" regard items of "CV risk factors" section of AHA 2009
EACPR	2011	PAR-Q v.2002	"Middle-aged/older sedentary individuals who wish to engage in low-intensity PA (<3 METS) are considered eligible without further evaluation, if the assessment of risk using validated questionnaires is considered negative"	- Defined ad age ≥35 years - Answer "NO" to all items of PAR-Q 2002

Table 1: (continued)

Algorithm	Version	Questionnaire	PPSAs' definition of subjects eligible for sport activity without medical evaluation	Subjects were defined eligible for sport activity without medical consultation (according to PPSAs' definition) if data in Med-Ex database allow to …
		PAR-Q v.2002	"If you answer NO to all PAR-Q questions, you can start becoming much more physically active and take part in a fitness appraisal"	- Answer "NO" to all items of PAR-Q 2002
		PAR-Q v.2020	"If you answered NO to all of the questions above, you are cleared for physical activity"	- Answer "NO" to all items of PAR-Q 2020

ACSM = American College of Sport Medicine; AHA = American Heart Association; EACPR = European Association of Cardiovascular Prevention and Rehabilitation; PAR-Q = Physical Activity Readiness Questionnaire.

data. Therefore, 464 male subjects (38.4 years ± 8.2 aged) have been considered as final study group.

Med-Ex protocol, including medical evaluation, detected 567 abnormalities: 175 (30.8%) blood pressure measures ≥130 and/or 85 mmHg, 165 (29.1%) hypercholesterolemia (at least >200 mg/dL), 131 (23.1%) abnormal Body Mass Index (BMI) values (at least >27), 55 (5.7%) ECG abnormalities (at rest and/or during EST), 21 (3.7%) impairing fasting glycaemia (100–125 mg/dL) and 20 (3.5%) abnormal physical examination (such as heart murmurs or unusual lung sounds) (see first column in Table 2).

On average, applying PPSAs alone, 24.2% (137.1 ± 99.7) abnormalities should have been "missed" (see fist row in Table 2). The abnormality most frequently missed by all simulated PPSAs, on average, was the high blood pressure (28.6%), followed by hypercholesterolemia (24.1%), impairing fasting glycemia (21.4%), BMI (21.3%) and abnormal ECG findings (19.1%) (see second column in Table 2).

As reported in Table 2, each PPSAs missed a different percentage of specific medical conditions (detected instead by Med-Ex protocol). EACPR (v.2011) + AHA (v.1998) missed the lowest number of abnormalities (25, 4.4%),

Table 2: Effectiveness of questionnaire-based PPSAs in detecting medical abnormalities in subjects considered eligible for PA.

Abnormalities detected in Med-Ex database (n=464 subjects) (n, %)	Missed abnormalities by all PPSAs mean n ± SD[a] (%)	Missed abnormalities by each PPSA							
		ACSM (v. 1998) with AHA (v. 1998) n (%)	ACSM (v. 1998) with AHA (v. 2009) n (%)	ACSM (v. 2014) with AHA (v. 2009) n (%)	ACSM (v. 2015) n (%)	PAR-Q (v. 2002) n (%)	PAR-Q (v. 2020) n (%)	EACPR (v. 2011) with AHA (v. 1998) n (%)	EACPR (v. 2011) with PAR-Q (v. 2002 n (%)
Overall abnormalities (n=567)	137.1 ± 99.7 (24.2%)	78 (13.7%)	55 (9.7%)	94 c(16.6%)	191 (33.7%)	298 (52.5%)	258 (45.5%)	25 (4.4%)	98 (17.3%)
Abnormal physical examination (n=20, 3.5%)	3.8 ± 4.1 (18.8%)	4 (20.0%)	2 (10.0%)	0 (0.0%)	2 (10.0%)	11 (55.0%)	9 (45.0%)	0 (0.0%)	2 (10.0%)
Impaired fasting glycaemia (100–125 mg/dL) (n=21, 3.7%)	4.5 ± 2.9 (21.4%)	5 (23.8%)	3 (14.3%)	2 (9.5%)	5 (23.8%)	10 (47.6%)	7 (33.3%)	1 (4.8%)	3 (14.3%)
BMI (n=131, 23.1%)	**27.9 ± 23.0 (21.3%)**	**12 (9.2%)**	**7 (5.3%)**	**12 (9.2%)**	**49 (37.4%)**	**62 (47.3%)**	**53 (40.5%)**	**6 (4.6%)**	**22 (16.8%)**
>27 and ≤29.9 (n=81, 14.3%)	19.4 ± 15.4 (23.9%)	9 (11.1%)	7 (8.6%)	9 (11.1%)	34 (42.0%)	43 (53.1%)	35 (43.2%)	4 (4.9%)	14 (17.3%)
>30 (n=50, 8.8%)	8.5 ± 7.7 (17.0%)	3 (6.0%)	0 (0.0%)	3 (6.0%)	15 (30.0%)	19 (38.0%)	18 (36.0%)	2 (4.0%)	8 (16.0%)
Hypercholesterolemia (n=165, 29.1%)	**39.8 ± 30.8 (24.1%)**	**25 (15.2%)**	**17 (10.3%)**	**25 (15.2%)**	**52 (31.5%)**	**89 (53.9%)**	**81 (49.1%)**	**6 (3.6%)**	**23 (13.9%)**
>200 and ≤250 mg/dL (n=145, 25.6%)	33.8 ± 26.4 (23.3%)	25 (17.2%)	14 (9.7%)	20 (13.8%)	45 (31.0%)	76 (52.4%)	68 (46.9%)	4 (2.8%)	18 (12.4%)
>250 mg/dL (n=20, 3.5%)	6.0 ± 4.8 (30.0%)	0 (0.0%)	3 (15.0%)	5 (25.0%)	7 (35.0%)	13 (65.0%)	13 (65.0%)	2 (10.0%)	5 (25.0%)

Table 2: (continued)

Abnormalities detected in Med-Ex database (n=464 subjects) (n, %)	Missed abnormalities by all PPSAs mean n ± SD[a] (%)	Missed abnormalities by each PPSA							
		ACSM (v. 1998) with AHA (v. 1998) n (%)	ACSM (v. 1998) with AHA (v. 2009) n (%)	ACSM (v. 2014) with AHA (v. 2009) n (%)	ACSM (v. 2015) n (%)	PAR-Q (v. 2002) n (%)	PAR-Q (v. 2020) n (%)	EACPR (v. 2011) with AHA (v. 1998) n (%)	EACPR (v. 2011) with PAR-Q (v. 2002 n (%)
High blood pressure (n=175, 30.8%)	**50.0 ± 33.8 (28.6%)**	**23 (13.1%)**	**20 (11.4%)**	**43 (24.6%)**	**73 (41.7%)**	**102 (58.3%)**	**89 (50.9%)**	**12 (6.9%)**	**38 (21.7%)**
High Normal (130–139 and/or 85–89 mmHg) (n=94, 16.6%)	23.9 ± 16.9 (25.4%)	18 (19.1%)	13 (13.8%)	29 (30.9%)	32 (34.0%)	44 (46.8%)	47 (50.0%)	1 (1.1%)	7 (7.4%)
Grade 1 (140–159 and/or 90–99 mmHg) (n=67, 11.8%)	14.5 ± 11.8 (21.6%)	4 (6.0%)	5 (7.5%)	7 (10.4%)	21 (31.3%)	36 (53.7%)	23 (34.3%)	3 (4.5%)	17 (25.4%)
Grade 2 (160–179 and/or 100–109 mmHg) (n=13, 2.3%)	3.6 ± 2.7 (27.9%)	0 (0.0%)	1 (7.7%)	2 (15.4%)	8 (61.5%)	5 (38.5%)	6 (46.2%)	3 (23.1%)	4 (30.8%)
Exercise-Induced (SBP >240 mmHg) (n=30, 5.3%)	8.0 ± 5.9 (26.7%)	1 (3.3%)	1 (3.3%)	5 (16.7%)	12 (40.0%)	17 (56.7%)	13 (43.3%)	5 (16.7%)	10 (33.3%)
Abnormal ECG findings (n=55, 9.7%)	**10.5 ± 7.9 (19.1%)**	**9 (16.4%)**	**6 (10.9%)**	**12 (21.8%)**	**10 (18.2%)**	**24 (43.6%)**	**19 (34.5%)**	**0 (0.0%)**	**4 (7.3%)**
at rest (n=14, 2.5%)	2.3 ± 2.1 (16.1%)	2 (14.3%)	1 (7.1%)	2 (14.3%)	1 (7.1%)	6 (42.9%)	5 (35.7%)	0 (0.0%)	1 (7.1%)
during EST (n=35, 6.2%)	6.6 ± 4.7 (18.9%)	6 (17.1%)	5 (14.3%)	9 (25.7%)	7 (20.0%)	13 (37.1%)	12 (34.3%)	0 (0.0%)	1 (2.9%)
both at rest and during EST (n=6, 1.0%)	1.6 ± 1.6 (27.1%)	1 (16.7%)	0 (0.0%)	1 (16.7%)	2 (33.3%)	5 (83.3%)	2 (33.3%)	0 (0.0%)	2 (33.3%)

[a]These data have been calculated as mean (and SD) of abnormalities missed by the set of PPSAs retrospectively simulated (PAR-Q (2002–2020)), AHA/ACSM (1998–2009–2014–2015), EACPR (2011) compared with Med-Ex protocol.

judging eligible for PA no abnormal ECG findings neither abnormal physical evaluation. On the other side, PAR-Q (v.2002) missed the highest number of abnormalities (298, 52.5%), including 58.3% of high blood pressure recordings, 34.5% of ECG abnormal findings and 49.1% of high cholesterol values. ACSM (v.1998) with AHA (v.1998) missed 23.8% of impairing fasting glycemia; ACSM (v.1998) with AHA (v.2009) missed 15.0% of hypercholesterolemia; ACSM (v.2014) with AHA (v.2009) 21.8% of ECG abnormalities and ACSM (v.2015) 61.5% of high blood pressure.

Discussion

The simulation analysis model designed in this study shows that, according to PPSAs based on self-administered questionnaires, one-fourth (24.2%) of medical and/or CV conditions, detected by Med-Ex medical evaluation, would have been missed. Therefore, subjects with these pathologic conditions would have been considered eligible for PA without any further examination. In particular, some of these conditions, such as high blood pressure, abnormal ECG findings and abnormal physical examination are quite alarming and would need to be further investigated. These findings highlight a worrying scenario, considering that our study group is composed by master and leisure time athletes (>35 years), mainly inactive, thus with a greater risk of cardiovascular fatal event [29].

In the literature, PPSAs are graphically reported as a flow diagram, in which the diagnostic results of each step are used to define the direction of the next step. In all graphical representation, the sedentary subjects, aimed to begin a low-intensity activity, represent the “most-extreme left arm of the algorithm" and this is the arm that has been simulated. The authors decided to adopt a "conservative model" with a "best scenario analysis": all subjects were considered to start a low intensity physical activity. However, the real scenario is also worse: indeed, some PPSAs allow some categories of subjects to directly perform higher intensity PA without previous medical consultations.

European association of Preventive Cardiology released its recommendation in 2011. It was the only algorithm to have a restriction about age (more than 35 years old): hence, we selected 118 subjects out of 464 for our simulation. The consensus group recommends that the first line of risk evaluation should be in the form of a self-assessment, using AHA (v.1998) or PAR-Q (v.2002). The first one would have missed only 25 abnormalities, while the second one 98: this is in line with what previously stated about the better "quality" of AHA questionnaire than PAR-Q one. Indeed, EACPR (v.2011) with PAR-Q (v.2002) missed 33.3% of high blood pressure (exercise induced), defined as SBP >240 mmHg [30]. Exercise induced high blood pressure has been related to an increase risk of future hypertension [31], stroke [32] and all-cause mortality [33]. So an early recognition of this condition could help to prescribe therapeutic programs of PA [34].

As previously stated, the PAR-Q questionnaires are often adopted as standalone methods [28] since these are globally recognized and used. However, from our reconstruction, these two versions (v.2002) (v.2020) missed respectively 298 and 258 abnormalities. In particular, PAR-Q (v.2002) missed 42.9% and PAR-Q (v.2020) missed 35.7% of abnormal ECG findings at rest, including a surgically corrected form of tetralogy of Fallot, that should require a specific rehabilitation [35] and a specific PA prescription [36]. Other ECG abnormalities, such as AF and left axial deviation, were missed by this PPSA, in contrast to International criteria for electrocardiographic interpretation in athletes [37].

ACSM (v.1998) with AHA (v.1998) missed almost a quarter of impaired fasting glycemia, defined as fasting plasma glucose levels between 100 and 125 mg/dL according to current guidelines [38]: this condition, also defined as prediabetes, is associated with an increased risk of cardiovascular disease [39] and all-cause mortality [40], and therefore should require a specific exercise prescription [41]. Also, this PPSA missed one significant ST segment depression on exercise stress test, a very strong predictor of sudden cardiac death [42]. According to this algorithm, apparently healthy and asymptomatic persons at increased risk (so defined "class A1, A2, and A3") may participate in moderate up to vigorous intensity exercise without a previous medical examination, showing a worse scenario than in our simulation.

A newer version of AHA questionnaire was released in 2009 and we retrospectively simulated ACSM (v.1998) with AHA (v.2009). It missed 17 hypercholesterolemia (>250 mg/dL), a key risk factor for CV disease [43]. Indeed, cholesterol level is a contributing factor in calculating RISK ESC score [44]. Therefore, screening for cholesterol level should be essential before allowing a master athlete to practice sport.

In ACSM algorithm (v.2014), a medical examination before exercise is not recommended both for low-risk patients undergoing a moderate and vigorous intensity exercise ("more conservative scenario" we simulated), and for moderate-risk patients undergoing a moderate intensity exercise. So, we retrospectively simulated ACSM (v.2014) with AHA (v.2009). A quarter of abnormal ECG findings (during EST) should have been missed: these are mostly represented by ventricular and supraventricular premature complex, and negative T waves. These abnormal ECG findings should be carefully evaluated according to International criteria for electrocardiographic interpretation in athletes [37], and should require further evaluation.

In 2015, a newer version of ACSM algorithm was released, focusing on the individual's current level of physical activity, on the presence of signs or symptoms of known cardiovascular, metabolic, or renal disease, and on the desired exercise intensity. More than a half of resting high blood pressure (grade II) would have been undetected. We defined blood pressure level according to current guidelines [30]. Its early recognition and treatment should be a primary objective in master athletes [45]. Moreover, this algorithm suggests to gradually progress to vigorous intensity exercise, increasing the risk for the subject itself.

According to these results, it is reasonable to adopt PPSAs using AHA questionnaire. Even if EACPR has a age restriction, it allows to screen older population and has shown the lowest percentage of missed abnormalities when adopted with AHA. Nevertheless, we have no data in the part of population aged less than 35 and we have to consider that other PPSAs have shown pathological condition even in this percentage of population. Therefore, it could be reasonable to adopt EACPR (v.2011) with AHA (v.1998) even in younger subjects, considering the simple methodology proposed by this algorithm and its accuracy.

To our knowledge, only another study performed a similar analysis. According to Ermolao et al. [15], applying EACPR (v.2011) algorithm would have missed 49% of previously undetected cardiovascular conditions, while ACSM (v.2014) and ACSM (v.2015) would have missed respectively 29 and 50%. However, this study did not specify the type of questionnaire adopted in EACPR reconstruction. Using PAR-Q as questionnaire can increase the percentage of subjects missed by this algorithm, as demonstrated in our study. Indeed, our reconstruction of EACPR with AHA questionnaire showed the lowest percentage of missed subjects.

Several criticisms emerge in our retrospective reconstruction of the PPSAs. First of all, different PPSAs are based on different rules that made difficult the process of reconstruction and simulation. Indeed, these questionnaires were not fulfilled by the subject itself at the exact moment of the visit, and the reconstruction was conducted by two medical doctors that could answer better to some questions, since that not all the questions present in PPSAs are easy to answer by a non-medical subject (i.e. "Have you ever had a coronary angioplasty?"). Obviously PPSAs are not as accurate as medical evaluation, but they are surely cheaper and easier to perform: these are important aspects to take in consideration when approaching a pre participation mass screening. Some PPSAs, such as 14-elements AHA PPSA [46], although proposed in scientific literature over the past years and worldwide used, were not included in this study because some clinical information, necessary to simulate the algorithms, were not routinely recorded during the Med-Ex examination. Finally, our sample size was composed by men only, so we don't know if gender could influence results.

Conclusions

In conclusion, our simulation analysis model allowed to show the limits of PPSAs for sports practice, in favor of a more responsible medical-guided CV screening. These findings emphasize the importance of reaching applicable and shareable solutions that guarantee a safer approach to sport practice in the general population, with the purpose of minimizing the CV risk related to sport practice.

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