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The development and optimisation of a quantitative physical fitness scoring system for use amongst Naval Service personnel

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ABSTRACT

Background: *A lack of research currently exists in relation to the current physical fitness testing system that is used within the Irish Naval Service, not only in relation to the tests that are used but also in relation to the scores that should be achieved in order to pass the test. As such the aim of this study was to select tests for various components of physical fitness and create a scoring system that could be used to assess individuals more comprehensively.*

Materials and methods: *Seventy-five individuals took part in the study (71 males, 4 females). Each participant completed a battery of physical tests analysing the following physical fitness components: flexibility, power, agility, strength, speed, anaerobic conditioning and aerobic conditioning. The mean score ± 0.67 and ± 1 standard deviations were used for the selection of categories.*

Results: *A six category scoring system was produced for each component of physical fitness. Scores were assigned to each category allowing a total cumulative score and an overall percentage of the total to be calculated. The categories are as follows: Score 5, Score 10, Score 15, Score 20, Score 25, Score 30.*

Conclusions: *A quantitative scoring system has been produced that allows comprehensive physical fitness testing to be conducted. In order to achieve a complete picture of a participant's physical fitness, all tests outlined should be included in the testing process. However, the flexible nature of this system allows for tests to be included or excluded to suit the needs of an individual or organisation. The fact that the scoring system is quantitative, the time involved is relatively short, multiple participants can be tested simultaneously and the pass rates can be decided upon by the host organisation makes this system versatile and comparable across multiple jurisdictions.*

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Key words: physical fitness, testing, scoring system, Naval Service

INTRODUCTION

It is imperative that physical fitness testing be conducted on individuals within naval service populations globally, and should be evaluated repeatedly over the career of Naval Service personnel. However, the time between each testing period varies according to the individual organisation. For example, within the American Navy, physical fitness testing takes place every 6 months [1], whereas in the Irish Naval Service testing takes place once a year [2].

Both of these organisations, as well as the British Royal Navy test participants through a 2.4 km run, a timed push-up test and a timed sit-up test [1, 3, 4]. These tests analyse two isolated components of physical fitness: aerobic conditioning and muscular strength. Whilst these tests have also been used within other military populations there is a lack of research to establish if these tests are fit for purpose or the occupational relevance of these tests within naval populations. Studies have suggested that other components

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of fitness or other tests could be used to test navy populations [5]. Examples include components which could be considered suitable for use within this population such as speed, power, flexibility, agility and anaerobic conditioning. Various laboratory and field tests are used for the examination of each of these components. However, each of these tests selected for use with the Irish Naval Service must be suitable for use with large numbers and require minimal portable equipment in the field. Additionally, there is also a lack of research around the scoring system that is used for the current tests. The aims of this study are to:

— design an appropriate set of physical tests that could be implemented both during recruitment and during the annual physical fitness assessments;
— construct a statistically relevant scoring system that can be used to monitor fitness levels on a periodic basis.

MATERIALS AND METHODS

PARTICIPANTS

In order to recruit participants, the aims and testing procedures were explained to all those serving on vessels within the Irish Naval Service fleet. Seventy-five individuals (71 males, 4 females) volunteered to take part in the study and once fully informed, a consent form was signed. Each participant then completed a battery of physical fitness tests over a 90-min testing period. All participants completed these tests between January and August of 2015.

TESTING

In order to produce a range of suitable physical fitness tests, research that already exists on navy, military, and seafaring populations was examined [5–9]. One test for each of the components of physical fitness including flexibility, agility, speed, strength, vertical power, horizontal power, anaerobic conditioning and aerobic conditioning was selected. Additionally, the timed sit-ups test and timed push-ups, which are currently being used as part of the fitness testing, were also included in the battery of tests. This allows the scoring system that currently exists to be broadly compared with the system produced by this study. All participants were required to perform a warm-up which consisted of 5 min of light running followed by four standard stretching exercises. All exercises in the warm-up were kept dynamic as this has been found to have a positive impact on performance [10].

Each of the tests conducted required minimal equipment, could take place indoors in a relatively small space and was suitable for testing large numbers of individuals. Where necessary, the equipment used for this study was calibrated annually, and testing always occurred in the same order, as outlined in Table 1 to minimise the effect of fatigue on the testing results. Some of the tests were only performed once due to the maximal nature of the test, whilst other tests were performed three times by each participant with a minimum of 30-s break between each one. The best score achieved was counted as the result for these tests after the three attempts. The assessment of flexibility took place prior to a warm-up in order to prevent the benefit of warm-up and stretching from influencing the results of the test. Additionally, due to the maximal nature of the multi-stage fitness test (MSFT) and the 5-m repeat shuttle run test participants were required to take a 30-min break between these tests. Tests were categorised and conducted as follows.

Table 1. Testing structure

Physical fitness element measured	Test	Number of times the activity is performed
Flexibility	Sit-and-reach	3
Warm-up		7 min
Vertical power	Counter movement jump	3
Horizontal power	Standing long jump	3
Agility	Pro agility	3
Strength	Dynamometer hand grip	3
Strength	Chin-up	1
Strength	Timed push-up	1
Strength	Timed sit-up	1
Speed	10-m and 20-m straight line speed	3
Anaerobic conditioning	5-m multiple shuttle run	1
Compulsory break		30 min
Aerobic conditioning	Multi-stage fitness	1
Cool down		6 min

The table above shows the format in which the testing was run. The left column displays the physical fitness component that was measured. The middle column shows the tests that were used in the order they were performed and the third column shows the number of times a test was performed by each individual.

FLEXIBILITY

The sit-and-reach test was selected to assess flexibility [11]. Good flexibility has been seen to have many benefits including reducing the risk of injury [12, 13]. This can be achieved through the incorporation of flexibility exercises into daily training. There are a range of various methods for testing the flexibility of various muscle groups. However, the sit-and-reach test has been seen to assess the flexibility of multiple muscle groups simultaneously and therefore could be seen as a more suitable test when only one flexibility

test is being used [14, 15]. Flexibility was measured using a sit and reach box. The participant was required to take off their shoes before performing the test. This test involved the participant sitting on the floor with legs straight and feet flat up against the sit and reach box. The participant reached as far forward as possible with their hands. The score was then measured to the nearest 0.5 of a cm from where the tips of the participant's hands stopped along the ruler.

VERTICAL POWER

A contact mat was selected to assess vertical power through a counter movement jump (CMJ) (FSL Electronics, Cookstown, Ireland). Whilst CMJ is not currently used in military setting it has been seen to be valid and reliable for assessing explosive power [6]. A study focused on women in the military found that a loaded explosive jump was linked to loaded carrying tasks [16]. Whilst further research is need to ascertain if this is also the case in an unloaded navy population this study will provide the norms for the Irish Naval Service should the research be conducted within another naval population. To test vertical power the participant started with two feet on the mat and hands on hips. The participant squatted to just above parallel then immediately jumped upwards with legs fully extended before returning to the mat. The contact mat measures the flight time and the height jumped for single jumps. Flight time was measured in 1/1000th of a second and was measured between when the participant leaves the mat and lands back on the mat. This flight time was used to calculate height jumped in 0.1 cm intervals.

HORIZONTAL POWER

Horizontal power was measured using a standing long jump test. A study involving the united states navy found that this test could be considered suitable for use within a physical fitness testing battery [5]. This test involved the participant starting with two feet behind a line and jumping as far forward as possible along a measuring tape which was secured to the floor. Participants were allowed to use arms to generate momentum. The recording was taken from where the participant's heels landed in line with the tape measure and was recorded in cm.

AGILITY

Although agility is not currently included in navy physical fitness testing, it could be a beneficial addition as it measures an individual's ability to move quickly and change direction in confined spaces such as on board a ship. The pro agility test was selected to assess this physical component as it has been found to be suitable for use within military populations and has already been researched as a possible new method of assessment within the United States Naval

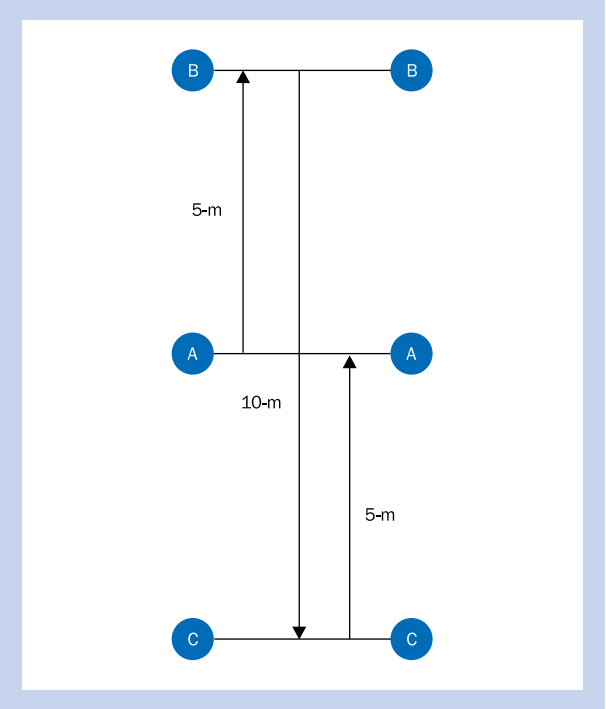

Figure 1. This figure above shows how the pro agility test is performed. The participant should start at line A, run 5 m to line B, run 10 m back through line A to line C, then turn and run the 5 m back to line A to finish. The time taken to finish is recorded and a single test score is assigned based on the details provided in Table 2; m — metres

Service [5, 17]. The use of a timing gate prevents human error from becoming a factor in the timing of this test. The pro agility test involved the participant completing the course as outlined in Figure 1. The participant completed the agility course three times with a break in between each repetition and the fastest time in seconds to the nearest two decimals was used for each participant.

STRENGTH

In order to assess strength a TKK 5401 Dynamometer (Takei, Japan) was used to measure hand grip strength in kilogram-force. Participants were instructed to bend their elbow to 90 degrees, keeping it tucked in close to the body and grip the handle as hard as possible with their strongest hand. The test was performed three times and the maximum score achieved was recorded. Hand grip strength has been seen to be necessary on board ships for the opening of overhead doors especially during emergency situations [7]. Therefore, perhaps the passing of this test should be a requirement prior to an individual commencing a sea-going rotation.

A maximal chin-up test was included to measure overhead strength. The participant started in a hanging position with palms of hands facing towards the participant on the

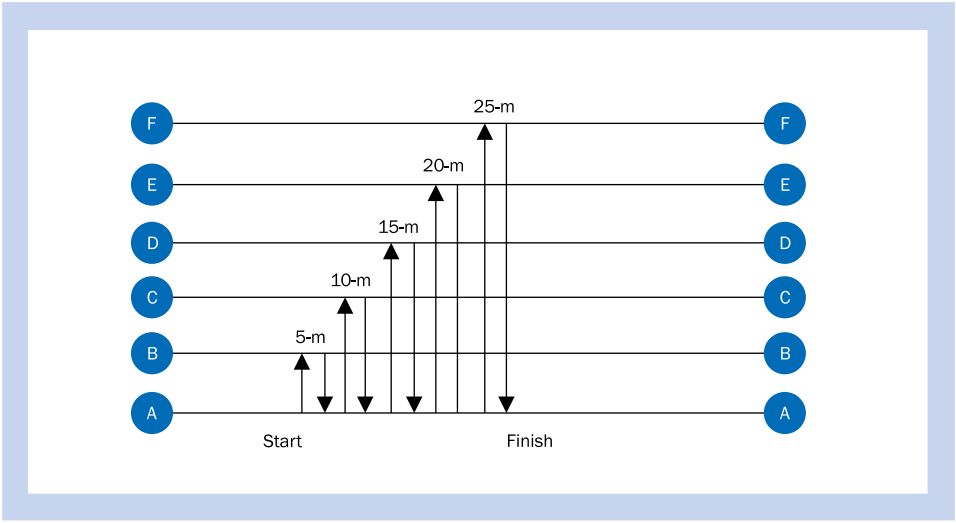

Figure 2. The figure above shows how the 5-m multiple shuttle run test should be performed. The participant would start at line A, run to line B then back to line A, run to C then back to line A and so on until the 30 s has elapsed. This is repeated six times with a 35-s break between each one. The figure also shows in metres the distance from line A to each other line. The distance completed during each 30 s is recorded and a cumulative score is recorded. A single test score is then assigned based on the details provided in Table 2; m — metres

bar and arms straight. The participant then used their arms to pull their chin above the bar before returning to the starting position. Each time the participant raises their chin above the bar it counted as one repetition.

In addition to these tests the standard 1-min timed sit-up and push-up tests were also included. For the sit-up test participants were instructed to cup their hands up over their knees for each repetition to count. In the push-up test participants were instructed to place hands shoulder width apart and lower their body to the ground until a 90 degree bend at the elbow was achieved. These tests assess strength endurance and are used within a number of military populations including the United States Navy [18] and the Australian Navy [19]. The chin-up, sit-up and push-up tests were only performed once with the score recorded after each test.

SPEED

Whilst the ability of an individual to move and change direction at speed may be measured by an agility test this does not provide an insight into an individual's aximum speed or ability to accelerate [20]. Performance of speed training has been seen to have a positive effect on other physical fitness components [21] and body composition negatively affects it [9]. Therefore, the inclusion of a speed test may enable a focus to shift to this area if needed. Speed can be measured over various distances; however, due to the small distances that would be performed on board a ship a 10-m and 20-m distance for speed was used for this study [9]. Speed was measured in seconds using timing gates placed at the start line, 10-m line and 20-m line. After completing four warm-up runs at increasing speeds then participants performed three maximal runs with a 1-min rest between each run. The shortest time needed to complete the 10-m and 20-m distances was recorded.

ANAEROBIC CONDITIONING

In order to measure anaerobic conditioning a 5-m multiple shuttle run test was used [22]. Various tests have been analysed for use within a navy population; however, there is a lack of research to ascertain which test is suitable. This test can be performed in a relatively small space and only takes 6 min 30 s to complete even with multiple individuals performing it at the same time. Participants were instructed to complete the course outlined in Figure 2 six times with a 35-s break between each repetition [23]. The course consisted of six cones placed 5 m apart along a line. The participants commenced at cone A, and upon hearing an auditory signal the subject sprinted to cone B, then back to cone A, sprinted to cone C then back to cone A and so on until the 30 s of exercise was completed. The distance obtained each time was recorded.

AEROBIC CONDITIONING

The MSFT was used to assess aerobic conditioning [24]. This test has been seen to be suitable for testing navy populations and it could be seen as more suitable than the 2.4-km run due to its inclusion of turning which is also essential to movement on board naval vessels [7]. This test involved the participants continuously moving over a 20-m

Table 2. Scoring system

Physical fitness element measured	Test and unit of measurement	Score 5	Score 10	Score 15	Score 20	Score 25	Score 30
	Average number of people per category	8	9	20	19	11	8
Flexibility	Sit-and-reach [cm]	< 11	11–13.5	14–18.5	19–22.5	23–25.5	≥ 26
Vertical power	Vertical jump [mm]	< 442	442–465	466–500	501–534	535–559	≥ 560
Horizontal power	Standing long jump [m]	< 1.59	1.59–1.71	1.72–1.89	1.90–2.07	2.08–2.20	≥ 2.21
Agility	Pro agility [s]	> 6.36	6.36–6.23	6.22–5.94	5.93–5.65	5.64–5.44	≤ 5.43
Strength	Hand grip	< 40.5	40.5–42.7	42.8–47.3	47.4–51.9	52.0–55.2	≥ 55.3
Current Naval Service tests (strength endurance)	Chin-up [reps]	< 1	1–3	4–6	7–9	10–11	≥ 12
	Push-up [reps per min]	< 27	27–32	33–39	40–46	47–52	≥ 53
	Sit-up [reps per min]	< 20	20–27	27–36	36–46	46–53	≥ 53
Speed	10-m speed [s]	> 2.05	2.05–2.01	2.00–1.92	1.91–1.84	1.83–1.78	≤ 1.77
	20-m speed [s]	> 3.60	3.60–3.50	3.49–3.35	3.34–3.19	3.18–3.08	≤ 3.07
Anaerobic conditioning	5-m multiple shuttle run [m]	< 537	537–558	559–590	591–622	623–646	≥ 645
Aerobic conditioning	MSFT [m]	< 859	859–1036	1037–1288	1289–1540	1541–1718	≥ 1719

The table above displays a scoring system for each test. The left-hand columns describe the component of fitness that is being assessed and the test that is used to assess this component. For each test there are six corresponding score categories and a score for each category. In each case the scores get better as the categories move from left to right; cm — centimetres; m — metres mm — millimetres; reps — repetitions; s — seconds; MSFT — multi-stage fitness test

distance in time to an audio signal. The test was finished when the participant could no longer reach the distance in time with the audio signal or the participant felt they could no longer continue. The last level that each participant fully completed was recorded as the score.

STATISTICS

SPSS statistical software, version 22 (IBM SPSS, U.S.A.) was used to analyse the data collected. Each test was assessed to check if it was normally distributed using a Shapiro-Wilk test. In order to establish the scoring system, the mean for each test was determined and used as the midpoint for the scoring system. Then, standard deviations (SD) of ± 0.675 and ± 1 were used to define each of the categories in the scoring system, producing results where approximately 50% of the data lay within the mean ± 0.675 SD, and approximately 68% of the data lay within the mean ± 1 SD.

RESULTS

A scoring system for each test of six categories was produced as outlined in Table 2 and was generated using the results of the 75 participants. However, importantly, these results are not the focus of this study but served mainly to create statistically relevant categories which could be assigned numerical and percentage based values to facilitate quantitative analysis. These categories were arbitrarily categorised as 'Score 5', 'Score 10', 'Score 15, 'Score 20', 'Score 25' and 'Score 30'. Depending on the score achieved, the participant's performance for that test was placed into one of these categories and obtained the corresponding score of 5 (Score 5), 10 (Score 10), 15 (Score 15), 20 (Score 20), 25 (Score 25) and 30 (Score 30). Once a participant obtained a score for each test, a cumulative score out of a maximum total of 360 was generated. The participant's final score was established when this numerical result was transformed into a percentage of the total (360). Each test was found to be normally distributed apart from the chin-up test which was still included in the scoring system as it was found to have occupational relevance for naval service personnel [7].

An example of how the scoring system works in practice is shown in Table 3, using three randomly generated sets of data including a total score and percentage. It is proposed that the assignment of a "pass rate" be left to each individual organisation or individual. The natural inclination is to set this rate at 40% to match many European academic standards. This may or may not suit individual organisations, however, who may want to set more specific pass rate targets for their participants. An advantage of this quantitative system is illustrated in Figure 3 where the relative progress of a number of individuals is tracked over a 3-year basis and is more informative than a binary pass/fail system currently employed by many organisations.

Table 3. Sample test results and scoring system results

Test and unit of measurement	Person A		Person B		Person C	
	Actual test result	Scoring system points	Actual test result	Scoring system points	Actual test result	Scoring system points
Sit-and-reach [cm]	22	20	8	5	7	5
Vertical jump [mm]	522	20	475	15	435	5
Standing long jump [m]	1.77	15	1.45	5	1.98	20
Pro agility [s]	5.40	30	6.02	15	6.51	5
Hand grip	48.9	20	48.4	20	49.4	20
Chin-up [reps]	15	25	8	20	2	10
Push-up [reps]	40	20	35	15	40	20
Sit-up [reps]	51	25	47	25	0	5
10-m speed [s]	1.76	30	1.98	15	2.11	5
20-m speed [s]	3.06	30	3.44	15	3.77	5
5-m multiple shuttle run [m]	625	25	570	15	570	15
MSFT [m]	1820	30	1440	20	800	5
Total score		290		185		120
Percentage of total		80.5%		51.4%		33.3%

The table above shows how the scoring system would work for three hypothetical individuals. The left column shows the test that was performed. After that each individuals has two columns. The first shows the score that they achieved for each corresponding test. The second shows the score that they individual would achieve in this scoring system for their result in each test. The bottom two rows show the total score that is achieved by each individual and the overall percentage; cm — centimetres; m — metres mm — millimetres; reps — repetitions; s — seconds; MSFT — multi-stage fitness test

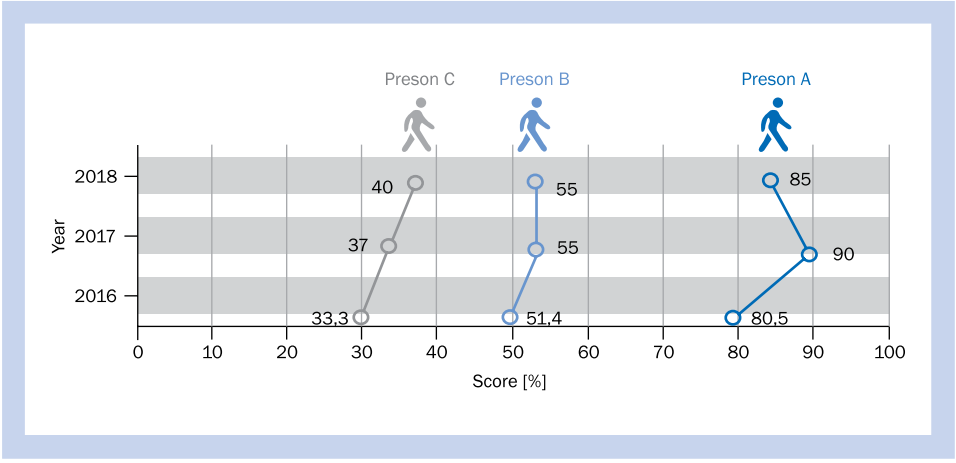

Figure 3. This figure shows the scoring system in a linear percentage model. It takes the three sample people as shown in Table 3 and shows how their physical fitness scores may progress over time. These fitness scores are based on the accumulated points achieved for each of the tests outlined in Table 1 which are then converted to a % (total score/360). This baseline score for 2016 (for example) can serve as a reference point for whenever the next series of identical tests are performed. In the figure above, these tests are repeated on an annual basis but can obviously be adopted based on the requirements of the testing organisation. Progress over time can thus be easily tracked and recorded using this visual model for each individual participant or for multiple participants at the same time

DISCUSSION

The aim of this study was to create a physical fitness testing system that could be used by a typical defence forces cohort. The physical fitness testing system is outlined in Table 1 and the scoring system to accompany this system can be seen in Table 2. This system allows individuals to be comprehensively tested over all aspects of physical fitness. Due to the fact that a scoring system has been produced for each individual test, the system allows for the inclusion or exclusion of any of the fitness tests outlined. This is

important because it would allow the organisations who implement this scoring system to establish which physical fitness elements are deemed to have most importance or occupational relevance. Future studies may indicate that for certain occupations within an organisation, additional physical fitness requirements are more relevant and, as such, this scoring system will allow for the physical fitness testing to be individually tailored.

Additionally, the current system used by the Irish Naval Service requires individuals to be able to pass all elements of physical fitness testing and if any one of these components isn't passed then the physical testing is failed. The results outlined in this study enable the use of a cumulative scoring system, rather than the current pass/fail, which enables the participants to be stronger or weaker in some categories than others and still achieve an overall passing result. Should future research dictate that certain components are essential to occupational performance then organisations can also implement stricter pass rates on specific tests.

As mentioned earlier, the selection of a "pass rate" is entirely subjective. An example of such a pass rate is found using the equivalent numerical scores for the three tests that are currently in use by some defence forces, *i.e.* 20 repetitions of sit ups, 20 repetitions of push-ups and running 1380 m in the MSFT [25]. In this scoring system, 20 repetitions of push-ups are in the 'Score 5' category resulting in a participant obtaining 5 points, 20 repetitions of sit ups sit in the 'Score 10' category resulting in participants obtaining 10 points and 1380 is in the 'Score 20' category resulting in participants obtaining 20 points. If these three results are averaged then participants would need an average of 11.67 points per test or a total of 140 out of 360 to pass (38.89%).

One of the advantages of this multi-test approach is the modular nature of the system allowing different organisations tailor the tests to produce a bespoke testing regime. Consequently, the inclusion of a number of these tests into physical fitness assessments could have many benefits for that organisation. For example, the inclusion of a flexibility test as a component of the annual physical fitness assessment could enable the identification of those at risk of injury due to inflexibility and prevent losses to the Naval Service in terms of both personnel and money [12, 13]. However, whilst ideally all 12 tests would be performed during a physical fitness examination sometimes this is not always feasible. As mentioned above the scoring system produced by this study does, however, enable the removal and insertion of tests if needed, as the calculation of scores is not dependent on each other.

Whilst this is the case, it is important to note that the performance in some of the tests may have been impacted by subsequent tests. An example of this would be the 5-m multiple shuttle run test and the MSFT. Both of these tests are considered to be maximal tests and are performed in this study with a compulsory 30-min break between them. As a result of having already completed a maximal test the participants in this study when performing the MSFT may have been suffering from some residual fatigue and therefore the MSFT results may have been lower than what would have been achieved in a non-fatigued situation.

The Irish Defence Forces currently states that completing the 2.4-km run test in a time of 11 min 40 s or less must be achieved in order to pass the 2.4-km run test. A study comparing the 2.4-km run with the MSFT found that this equates to achieving level 8 and 8 shuttles or 1380 m [25]. The results of this study suggest that the minimum score that should be obtained in order to sit in the "average" category is 1037 m or level 7 and 1 shuttle. However, as outlined above, the testing participants completed a maximal anaerobic test 30 min before completing the MSFT. This means that the results of this study would only be valid for use when conducted in conjunction with a maximal anaerobic test.

The results that have been found in this study have not been separated according to age or gender with the exception of the push-up test which allows different protocols for male and female participants. Female participants were allowed to perform push-ups on their knees as this is the current protocol implemented by the Irish Naval Service. However, the results were still included in the scoring system as it did not affect the average number of push-ups performed (average with females 40.2, average without females 40).

Not only does the Irish Naval Service currently have different protocols for push-ups but it also has different scoring levels for some of the physical fitness components, divided according to both age and gender. Over the last number of years it has become increasingly more inappropriate to discriminate against somebody based on age or gender. In addition to this, the individuals on board vessels are divided according to occupation and not age or gender. This means that individuals aged 45 must be able to perform the same tasks as 25-year-old counterparts and female are expected to perform the same tasks as male counterparts. Therefore, it could be argued that physical fitness scores should be standard and not divided according to an age or gender bias.

CONCLUSIONS

The quantitative scoring system that has been produced allows for the comprehensive physical fitness testing of individuals. Although testing was conducted on personnel within the Irish Naval Service, the standardisation and adaptive ability of the testing would allow its implementation within any organisation. Its cumulative and flexible

nature then allows the organisation to tailor the system to individual or organisational requirements. Additionally, the entire testing system can take place in a relatively small location, requiring limited equipment. Participants complete the test on average in under an hour and a half and multiple individuals can perform the testing simultaneously which reduces time wastage.

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