Can Baseline Recruit Characteristics Predict Actual Injuries Sustained During New Zealand Army Basic Training?

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Can Baseline Recruit Characteristics Predict Actual Injuries Sustained During New Zealand Army Basic Training?

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ABSTRACT

Introduction:

Certain army recruits entering basic training may be at heightened risk of injury. It is unknown if risk factors for lower limb injuries could be identified upon entry to basic training for New Zealand Army recruits. This study investigates if personal, lifestyle and physical performance characteristics reported at entry to training could identify recruits who go on to sustain a lower limb musculoskeletal injury during New Zealand Army basic training.

Materials and Methods:

Recruits' baseline personal (age, sex, and BMI), lifestyle (history of smoking and previous injury) and physical performance characteristics (2.4 km timed run outcome, ankle range of motion using the weight-bearing dorsiflexion lunge test and lower limb dynamic control using the Y Balance Test) were collected at entry to basic training. Backwards stepwise logistic regression analyses were undertaken to determine if baseline variables predicted the occurrence of an injury during basic training and to determine the optimal model of prediction. Significance was set to 0.10. This study was approved by Commander of TRADOC NZDF February 2012 and from Griffith University Human Research Ethics Committee May 2012 (PES/36/11/HREC).

Results:

In total 248 recruits, 228 males and 20 females, were eligible to participate in the study. Forty-six (18.5%) recruits had missing data thus, 202 (81.5%) remained for analysis. There were 114 recruits who reported one or more injuries, and 88 recruits reported no injury. Two variables were associated with injury risk in the final model: passing the 2.4 km timed run and Y Balance Test average normalized posterolateral reach for the right limb. This model accurately predicted 60.9% of recruits with 36 correctly assigned as not injured and 87 correctly assigned as injured.

Conclusions:

This study identified that 2 physical performance characteristics were associated with lower limb injury in New Zealand Army recruits commencing basic training; not passing the entry 2.4 km timed run, and low right posterolateral Y Balance Test score for lower limb dynamic neuromuscular control. These findings suggest that physical performance screening may be used to identify recruits at high risk of injury entering training so that mitigation measures could be implemented to lower future injury risk.

INTRODUCTION

High incidences of injuries are sustained by recruits during basic training leading to substantial training time loss, career alteration and economic and operational readiness consequences.[1,2] Recruits entering Army basic training with suboptimal physical fitness and adverse lifestyle characteristics such as previous injury and a history of smoking may be at heightened risk of injury.[3,4] By accurately identifying recruits at higher risk of injury entering basic training, mitigation measures could be taken, potentially resulting in reductions in injury incidence and associated injury burdens for both recruits and the military. The challenge is selecting injury risk measures suitable and effective for mass screening of recruit populations that are likely to be adopted by small and resource limited military training establishments.

Research investigating injury screening or prediction tests to identify injury risk for military populations is emerging.

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Screening tests have included existing military fitness tests as standalone[5–8] or combined with surveys and physical performance tests such as the Functional Movement Screen, Y Balance Test for lower limb dynamic neuromuscular control and ankle dorsiflexion range of motion.[9–11] Others have investigated screening tests that only include functional movement tests (Functional Movement Screen, Y Balance Test, Landing Error Score System, Overhead Squat).[12] Predictive risk algorithms for re-injury following an initial musculoskeletal injury have also been reported.[13]

Limitations exist with the application of some screening tests to recruit populations. For example, the Functional Movement Screen[14] while thorough, requires additional time, equipment and staff to conduct and may not be feasibly implemented because of constraints of a busy recruit training program.[12] Additionally, injury screening research performed with trained military personnel[9–11] may not be representative of younger, inexperienced recruit basic training populations. Even when screening tests are performed with recruits, screening may be limited to a single test such as ankle dorsiflexion range of motion,[15] a single injury type such as patellofemoral pain[16] or report exclusively male[5,16] or female recruit populations.[7]

Ideally, screening tests need to be cost, resource and time efficient, use existing staff and be applicable in a range of military training environments (classroom, field-based) whilst also fitting around the existing training program and constraints of a regimented military recruit training establishment.[5] Such screening tests should include data of recruit personal characteristics (sex, age, weight, height),[17] military fitness test results,[7,8] and preferably use simple low cost physical performance tests with known ability to identify higher lower limb injury risk in military and sports populations such as ankle dorsiflexion range of motion[10,15,18] and lower limb dynamic neuromuscular control.[11,16,19,20] Additionally, responses from surveys like the Military Pre-training Questionnaire can give insight into self-reported pre-entry lifestyle characteristics of recruits including physical fitness, injury history, diet/nutrition status, alcohol consumption, and smoking history.[3,21] Results of screening tests can then be compared to actual injuries sustained by recruits during basic training to ascertain their effectiveness.

It is currently unknown if risk factors for common musculoskeletal lower limb injuries in New Zealand Army recruits can be identified upon entry to basic training. The aim of this study was to investigate if baseline personal, lifestyle and physical performance characteristics recorded at entry to training could identify recruits who sustained lower limb injury during New Zealand Army basic training.

METHODS

Study Design and Participants

This prospective cohort study included male and female regular force Army recruits (≥17 years old) across 2 consecutive intakes of approximately 140 recruits, with 4 platoons per intake. Recruits commenced basic training in the New Zealand central North Island in 2012. Recruits who provided informed consent were included, although those who did not consent, declined attestation or who re-joined basic training after Week 1 because of being backsquadded from previous intakes were excluded from the study. Additionally, recruits who did not seek medical attention for an injury were not able to be recorded and, therefore, excluded from the study.

Measures

Personal, lifestyle and physical performance characteristics

All personal, lifestyle, and physical performance characteristics were recorded in Week 1 of basic training for all participants, with formal military training commencing from Week 2. Personal characteristics included sex, age, height (cm), weight (kg), and Body Mass Index (BMI). Lifestyle characteristics, including pre-entry physical fitness, injury history, diet, alcohol, and smoking status, were recorded using the self-reported Military Pre-training Questionnaire.[3,21]

Physical performance characteristics including aerobic fitness test results using the 2.4 km timed run, ankle dorsiflexion range of motion using the weight-bearing dorsiflexion lunge test,[18] and lower limb dynamic neuromuscular control using the Y Balance Test[19,20] were recorded. The timed 2.4 km run was administered by Army physical training instructors, with results recorded using a stopwatch. The weight-bearing dorsiflexion lunge test and Y Balance Test were administered by 2 Army Reservist physical therapists and/or an Army remedial instructor. Further details regarding the tests have previously been described.[22]

Injury incidence

Injury incidence was defined as any health care encounter for a new lower limb injury sustained during basic training.[17,23] Lower limb injury was defined as presentations of any symptoms that resulted in the recruit obtaining a health encounter and occurred entirely or in part as a consequence of trauma sustained during basic training;[24] including aggravation of a preexisting injury.[17] Multiple new lower limb injuries to the same recruit were included separately, and simultaneous bilateral presentations such as medial tibial stress syndrome were counted as 2 individual new injuries. This was to ensure more accurate capture of the total injury problem[23] based on medical record reporting.

Lower limb injury reported by recruits to the medical center, or the field medic were recorded on the local electronic medical database by camp-based medical staff (doctors, nurses, medics, physical therapist, and remedial instructor). Lower limb injuries were subdivided into anatomical body regions which included: the foot, ankle/Achilles, shin/calf, knee, thigh, hip/groin/pelvis, skin/nail, and cramps. Lower limb conditions for skin such as blisters or cellulitis, ingrown toenail, and muscle cramp were also included as injuries. Recruits with no injury reported, were also included. Injury data were tabulated by the lead author (NH) and analyzed in Microsoft Excel (Version 2010) tables after completion of basic training.

Analysis

Descriptive analyses were undertaken of recruits' baseline personal, lifestyle, and physical performance characteristics.[22] Variables for inclusion into the predictive model were identified from previous research which had shown ability to identify lower limb injury risk in military recruits, sports, and healthy young adult populations. Personal characteristics included age,[4] sex, and BMI.[25] Lifestyle characteristics included a previous injury[3,4] in the last year and a history of smoking.[4] Physical performance characteristics included pass results of the 2.4 km timed run for aerobic fitness[3,7,8] (A pass grade for New Zealand Army recruits aged 25 years or less for males is 10.5 minutes and females is 12.3 minutes), the weight-bearing dorsiflexion lunge test[18] and the lower quadrant Y Balance Test for lower limb dynamic neuromuscular control.[19,20] Ankle dorsiflexion range of motion was recorded as average maximum reach for distance in centimeters (converted from degrees),[15,18] and asymmetry difference (>1.5 cm or equivalent degrees).[10,26] Lower quadrant Y Balance Test was normalized to leg length [measured from the anterior superior iliac spine to distal medial malleolus (cm)][20] and recorded as posterolateral reach direction for right and left limbs (%), posterolateral asymmetry difference (cm),[16] and average combined composite score (%) which included all 3 Y Balance Test reach scores (anterior, posteromedial and posterolateral).[19,27]

For each variable, a logistic regression was performed to determine how well the variable predicted the occurrence of an injury in this dataset. All variables were then entered in a backwards stepwise logistic regression to determine the optimal model to predict the occurrence of an injury in this dataset. As is common with backwards logistic regression, the probability of entry to the model was set at a value less than the probability of removal from the model so that the addition of a variable at 1 step does not mean it is removed at the next step.[28] For this reason, the significance was set at 0.05 for entry to the model and 0.10 for removal from the model. Analysis was performed using IBM SPSS Statistics (Version 29).

Ethical approvals

Ethical clearance was granted by the Commander of Training and Doctrine from the New Zealand Defence Force in February 2012 (Updated 2019) and from Griffith University Human Research Ethics Committee in May 2012 (PES/36/11/HREC).

RESULTS

The flow of recruits through the trial is detailed in **Figure 1**. Potential participants included 281 Army recruits from 2 consecutive intakes and 8 platoons. Thirty-three were excluded from the study; including 5 who did not consent. In total 248 recruits, 228 males and 20 females, were eligible to participated in the study. Forty-six (18.5%) recruits had missing or incomplete data, which resulted in 202 (81.5%) complete sets of recruit data remaining for analysis. There were 114 recruits with one or more injuries and 88 reported no injury. Recruit baseline personal demographics, lifestyle and physical performance characteristic results from Week 1 of training have been previously reported.[22]

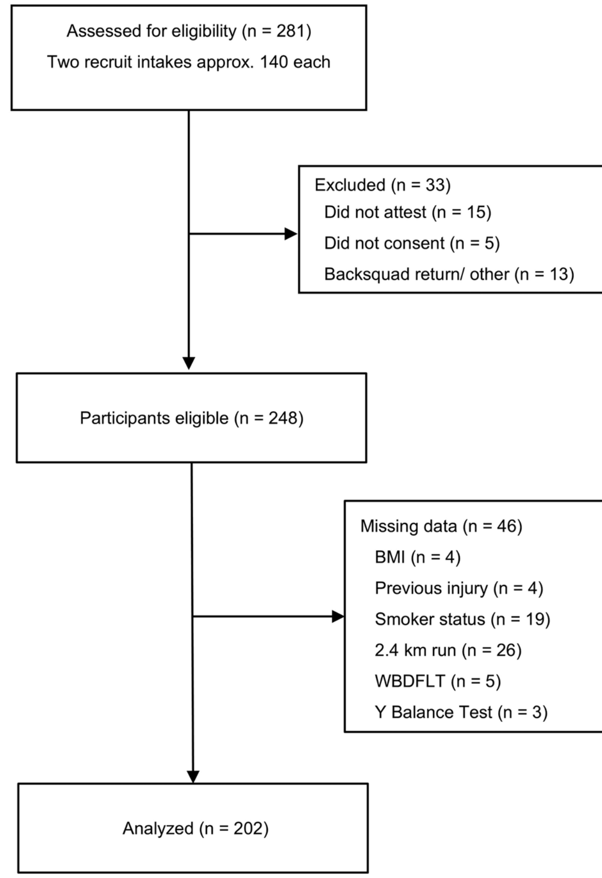

Figure 1. Flow diagram of recruits through the study.
Reproduced under [Thesis/Licenses CC BY-NC-SA 4.0]. [Australian Catholic University/Hall, N., Constantinou, M., Kuys, S., Beck, B., Brown, M., Steele, M. and Rousseau, J.. (2024). Injuries in New Zealand Army Recruits [PhD Thesis]. Australian Catholic University https://doi.org/10.26199/acu.911zy

Variables not significant in the final model were the personal characteristics of sex ($P = .152$), age ($P = .635$), and BMI ($P = .615$); lifestyle characteristics of previous injury ($P = .340$) or history of smoking ($P = .166$) and physical performance characteristics for weight-bearing dorsiflexion lunge test average maximum distance ($P = .257$) or asymmetry in centimeters ($P = .591$), and for Y Balance Test were left-sided posterolateral reach normalized to leg length ($P = .737$), posterolateral asymmetry ($P = .147$) and combined composite score ($P = .677$).

Of the 12 univariate logistic regressions, only 2 of the 12 variables identified were significant. Passing the 2.4 km timed run ($P = .067$, CI 95% 0.355 to 1.035) and Y Balance Test average normalized posterolateral reach for the right limb ($P = .069$, 95% CI 0.015-1.169) identified recruits at risk of sustaining a lower limb injury from Week 1 of basic training.

The backwards stepwise logistic regression had 2 significant variables associated with injury risk in the final model. The 2 variables were passing the 2.4 km timed run ($P = .018$) and Y Balance Test average normalized posterolateral reach for the right limb ($P = .102$) (see **Table 1**). The *P* value for the Y Balance Test average normalized posterolateral reach for the right limb was slightly above 0.10. Although not statistically significant because of the probability of removal from the model being set at the arbitrary 0.10 value, this was included in the final model as the main aim of analysis was to identify variables linked to injury prediction. This model accurately predicted 60.9% of recruits (36 were correctly assigned as not injured and 87 were correctly assigned as injured).

DISCUSSION

To mitigate risk of injury during New Zealand Army basic training requires initially identifying recruits at high risk of injury at entry, and to see if modifiable factors could be addressed to lower that risk. Results from this study address the first concept by examining the relationship between the presence of injury risk factors on entry to New Zealand Army basic training and actual injuries sustained by recruits during training. We found that recruits entering basic training with low aerobic fitness and reduced lower limb dynamic neuromuscular control for right limb were most at risk of sustaining a lower limb injury.

Recruits entering training with low physical fitness (slow 2.4 km run time) were at greater risk of sustaining a lower limb injury. This finding is perhaps not surprising. Substantial research exists supporting a strong association of low entry fitness and a greater risk of injury during basic training across Army,[3,7,8,25,29] Marine Corps, and Air Force recruit populations.[30,31] In fact, the slower the run time, the greater the risk for injury has been demonstrated.[7,25] Low physical fitness at entry suggests recruits may not be conditioned appropriately to cope with the arduous challenges of basic training[3] leading to greater overall fatigue and this may increase injury risk.[29] Additionally, perhaps too much time could have elapsed between the recruitment fitness test and Week 1 entry testing, resulting in aerobic fitness deconditioning of prospective recruits.[7]

Aerobic fitness as measured by 2.4 km timed run is a modifiable intrinsic recruit injury risk factor. Ideally, if prospective recruits train to exceed the minimum 2.4 km pass time requirements pre-entry, and if military recruitment adheres to run time cutoff standards, it is likely to result in fewer lower limb injuries occurring during New Zealand Army basic training. The challenge for militaries is finding a balance between achieving recruitment quotas and finding enough recruits meeting entry fitness requirements. Preconditioning programs for low fitness recruits delivered before formal basic training have demonstrated a tendency for lower risk of injury and reduced attrition in male and female United States Army recruits.[32] Preconditioning programs warrants further research investigation to address entry of low fitness recruits and risk of injury in the New Zealand Army.

Low dynamic neuromuscular control of the lower limb was also a risk factor for injury in our study. A significant association was identified between low Y Balance Test posterolateral score which reports limb dynamic control, and injury risk of the right lower limb. The combination of low hip strength,[33,34] greater movement complexity,[35] low visual input,[36] and limb dominance performing the Y Balance Test posterolateral direction, may help explain why these results were significantly different compared to the left limb or the composite score in this study. Reduced hip girdle muscle strength required to maintain stability of the pelvis and trunk throughout the Y Balance Test may contribute to this finding.[33] Low isometric hip strength, particularly hip abduction, has been associated with low posterolateral dynamic neuromuscular control performance using the Y Balance Test in previous studies.[33,34] New Zealand Army recruits with low dynamic control scores for posterolateral reach, potentially may have low hip abduction strength, and this appears to be isolated to the right limb. Posterolateral reach requires greater movement complexity with increased pelvic rotation[35] and balance, likely because of limited visual input (inability to see the reach indicator).[36] These performance factors may explain some of the varied Y Balance Test results reported compared to other reach directions.

Low right-sided lower limb dynamic neuromuscular control as a risk factor for injury may also be related to limb dominance. Low right-sided posterolateral dynamic neuromuscular control suggests asymmetry exists in performance in this cohort of Army recruits, although it is unclear if the dominant or non-dominant limb performs better on dynamic neuromuscular control testing. Limb dominance was not reported in this

Table 1. Results of Logistic Regression for the Relationship Between Baseline Data and Injury Occurrence in Army Recruits

Variable	OR (95% CI)	*P*-value
Personal		
Sex	2.75 (0.69-10.97)	.152
Age (years)	1.03 (0.91-1.16)	.635
BMI (kg/m^2)	0.97 (0.88-1.08)	.615
Lifestyle		
Previous injury	1.37 (0.72-2.64)	.340
History of smoking	1.51 (0.84-2.72)	.166
Physical characteristics		
2.4 km timed run pass (min)	0.50 (0.28-0.89)	.018
Weight-bearing dorsiflexion lunge test		
Maximum reach (cm) average	1.06 (0.96-1.16)	.257
Asymmetry (cm)	0.94 (0.76-1.17)	.591
Y Balance Test normalized		
Posterolateral (%) right	0.13 (0.1-1.49)	.102
Posterolateral (%) left	0.35 (0.00-165.89)	.737
Posterolateral asymmetry (cm)	0.95 (0.88-1.02)	.147
Composite score combined (%) average	1.02 (0.94-1.10)	.677

Abbreviation: BMI, body mass index.

cohort, and therefore it is unclear if limb dominance contributed to the difference in limb performance with posterolateral dynamic neuromuscular control and recruit injury risk. Limb dominance, however, was not found to be significant for Y Balance Test dynamic neuromuscular control performance in 2 studies, including one in a population of young adults[37] and another of healthy participants.[33] Given the low cost and time for testing, findings support use of dynamic neuromuscular control using the Y Balance Test posterolateral reach to identify recruits at high risk of injury on entry to training.

Other physical performance tests of dynamic neuromuscular control were not associated with lower limb injury in this cohort of New Zealand Army recruits. This finding was unexpected as previous research using the Y Balance Test (modified Star Excursion Balance Test) normalized composite score found higher injury risk using cut points below 89.6% and 94% in sports populations.[19,27] Previous research has also found no association of injury risk to Y Balance Test performance across 4 United States military recruit populations (Army, Navy, Air Force and Marine Corps active duty applicants).[38] However, injury in that study was defined as an episode of pain and specific injury incidences were not reported.[38] The relationship between Y Balance Test performance and injury risk remains unclear. Potentially, the Y Balance Test may perform better as part of a multifactor risk model, and investigation of sex, age, sport or military unit, and country-specific cut points are required to better determine its association to recruit injury risk in future research.[39]

Results of the current study support the use of physical performance injury screening consisting of aerobic fitness and lower limb dynamic neuromuscular control testing for Y Balance Test posterolateral direction in New Zealand Army recruits at entry to training. Other benefits of injury screening include providing an opportunity for initial health screening, builds rapport between the medical team and incumbent recruits, is important for medicolegal duty-of-care requirements,[40] and provides baseline measurement of personal, lifestyle, and physical performance characteristics.

Strengths

This sample is representative of six months regular force New Zealand Army basic training recruits and includes males and females. All lower limb injury types, injury mechanisms, and conditions commonly effecting recruits such as skin, nail, and cramps were included. Multiple and bilateral injuries were reported individually which potentially, is more thorough than studies limited to first time injury or time to first injury reporting.[23] Collectively, this dataset likely represents the actual extent of the recruit injury problem. Other strengths of the study include blinding of outcome assessors for injury presentations (Doctors, nurses, medics, and remedial instructor) and physical performance tests (Physical training instructors, Army Reservist physical therapists). Additionally, the weight-bearing dorsiflexion lunge test and the Y Balance Test outcome measures were chosen for their low cost, time, and resource efficiency (2.4 km run test already exists) and proven association identifying risk of injury in some military and sports populations.

Limitations

Forty-six recruits had incomplete or missing data, leaving 202 for inclusion in the logistic regression analysis. This limitation for the most part, reflects the logistical constraints of collecting research data during recruit basic training as regimental and Army medicals took priority. Because few females entered basic training, data for the current study were reported combining results of both sexes, therefore sex-specific outcomes were not thoroughly investigated. Additionally, injuries sustained by recruits that were not reported to the medical center were not recorded; this could underestimate recruit injury. Limb dominance was not collected, therefore data for some physical characteristics were averaged for right and left lower limbs. Investigation of limb dominance, previous injury recovery status such as fully recovered or not, and female menstrual history upon entry to training may be useful to include in future injury risk research models.

CONCLUSIONS

This study investigated whether personal, lifestyle and physical performance characteristics could identify lower limb injury risk in New Zealand Army recruits commencing basic training. Recruits with a slow 2.4 km run time at entry to basic training were more likely to sustain a lower limb injury than recruits who passed the run time requirement. Recruits with low right posterolateral score for lower limb dynamic neuromuscular control were identified as at greater risk of injury during basic training. These findings support the use of entry physical performance injury screening and adherence to 2.4 km run time cut points pre-entry to potentially lower recruit injury risk training. Research that investigates baseline characteristics and injury risk at entry to training is now required with larger numbers of New Zealand Army recruits, and over longer periods.

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CONFLICT OF INTEREST STATEMENT

The lead author (N.H.) worked as a physiotherapist for the New Zealand Defence Force in camp during this study period.

DATA AVAILABILITY

Data cannot be shared for ethical/privacy reasons. Data are owned by third party. The data underlying this article cannot be shared publicly for the privacy of individuals who participated in the study.

INSTITUTIONAL REVIEW BOARD

Ethical clearance was granted by the Commander of Training and Doctrine from the New Zealand Defence Force February 2012 (Updated 2019) and from Griffith University Human Research Ethics Committee May 2012 (PES/36/11/HREC).

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE

Not applicable.

INSTITUTIONAL CLEARANCE

Permission was granted to publish this paper November 19, 2024 from the Principal Advisor Organizational Research, People Capability Portfolio, Headquarters New Zealand Defence Force.

INDIVIDUAL AUTHOR CONTRIBUTION STATEMENT

N.H. conceptualized theme, data collection, analyzed data, wrote and edited paper, S.K. conceptualized, edited, analyzed data, M.B. conceptualized, edited, B.B. editing, M.S. assisted statistical analysis, editing, J.R. military industry expert, edited, and M.C. conceptualized, edited, analyzed data. All authors read and approved the final manuscript.

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