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**Cardiorespiratory fitness is a risk factor for lower-limb and back injury in law enforcement officers commencing their basic training: a prospective cohort study.**

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**Running Title:** Basic training injury epidemiology in Police Force recruits

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**Cardiorespiratory fitness is a risk factor for lower-limb and back injury in law enforcement officers commencing their basic training: a prospective cohort study.**

## Abstract

We aimed to report the epidemiology of lower-limb and lumbosacral injuries in Police Force recruits. We performed a cohort study of Police Force recruits undergoing a six-month training program with prospective injury data collected between 2018-2021. Cardiorespiratory fitness was quantified by the beep-test and police-specific-functional-capacity was quantified using a specifically designed physical performance evaluation (PPE) tool. Injury frequency and prevalence were reported. Fifteen percent (n=180) of study Police Force recruits (n=1,181) sustained a lower-limb or lumbosacral injury. The six-month training program significantly improved cardiorespiratory fitness ($p<0.001$) and functional capacity ($p<0.001$). Increased cardiorespiratory fitness at baseline decreased injury risk (OR=0.8, 95%CI: 0.66-0.97, $p=0.019$). Injury rates decreased over time and females were injured significantly earlier than males (OR = 0.70, 95%CI: 0.52 to 0.95, $p=0.021$). Interventions that can pre-condition Police Force recruits prior to the commencement of their basic physical training may reduce the number of lower-limb and lumbosacral injuries.

**Keywords**

Injury; police; prevention; epidemiology

## Introduction

Police officers worldwide typically undergo a recruit training program prior to graduating and commencing as qualified, operational front-line officers (Tomes et al., 2020). These training programs include vigorous combinations of physical, combat, and weapons handling training (Merrick et al., 2022) and are designed to prepare police recruits for the strenuous and volatile requirements of their active duties. It is vital for law enforcement officers to receive intensive physical training, given the potential performance requirements and high risk of injury associated with their work (Brandl & Stroshine, 2003, 2012). However, similar to other populations performing vigorous physical activity (e.g., athletes and military recruits) (Ekegren et al., 2015; Murphy et al., 2022b), illness and injury are common during recruit training (Murphy et al., 2022a).

Injury incidence rates among law enforcement recruits were quantified in a recent systematic review (Murphy et al., 2022a). This review demonstrated that medical-attention injury prevalence was between 13.7 to 24.5% with an injury incidence rate for law enforcement recruits between 1.67 to 4.24 new injuries per 1000 training days (Murphy et al., 2022a). However, at the time of this review, time-loss injury epidemiology had not been reported for law-enforcement recruits (Murphy et al., 2022a). Subsequently, a recent analysis of the Western Australian (WA) Police Force recruit injury database determined the prevalence of recruit time-loss injury to be 20.1%, with an incidence rate of 1.74 injuries per 1000 training days (Merrick et al., 2022). This study also examined the effect of recruit age and sex on injury occurrence (Merrick et al., 2022). Being older than 30 years of age increased injury risk by 60% ($p=0.002$) and being of female sex increased injury risk by 80% ($p<0.001$) (Merrick et al., 2022). These findings align with other research in Federal Bureau of Investigation (FBI) recruits, that reported older age being a risk factor for injury (Knapik et al., 2011).

The influence of recruit cardiorespiratory fitness and complex police-specific functional capacity on injury risk has received little attention to date (Merrick et al., 2022). One study of police recruits demonstrated that higher fitness levels increased the chance of successfully completing training (Lockie et al., 2019). Similarly, a study of FBI recruits demonstrated that poorer fitness increased injury risk (Knapik et al., 2011). However, small numbers of participants in these studies limits the confidence and generalisability of their findings. All injuries sustained during training have previously been the outcome measure of risk factor analyses, without consideration of different body areas and the potential that risk factors differ between body area. For example, one study by Orr et al. 2016 found that vertical jump height was associated with injury, but only explained 1% of the variance in injury rates. This may be due to the inclusion of all injuries as an outcome measure in their study, even injuries which are unlikely to be related to jump height, like wrist injuries.

All existing studies exploring physical risk factors for injury in law enforcement recruits have included injuries to all body regions (Knapik et al., 2011; Lockie et al., 2019; Orr et al., 2016). Unfortunately, this approach can overly-generalise the injury pool by including injuries whose region would not typically be associated with the risk factor (e.g., an elbow sprain is unlikely to be related to running endurance). This is particularly relevant when the majority of injuries (and the associated time-loss burden) sustained by police recruits are in the lower-limb (Merrick et al., 2022). While including all injuries may be appropriate for analyses of age or sex, by only examining injuries that are rationally related (i.e., lumbopelvic and lower-limb) to the risk factors of interest, such as fitness, a more meaningful analysis can be conducted.

The objectives of this study were to report the frequency, proportion and prevalence of lower-limb and lumbosacral injuries in WA Police force recruits undergoing physical training. We also aimed to examine whether a six-month WA Police force recruit training program improves cardiorespiratory fitness and police-specific functional capacity, determine the relationship between cardiorespiratory fitness and police-specific functional capacity on lower-limb and lumbosacral injury occurrence and explore the temporal change in injury risk throughout the recruit training program.

## Methods

### *Study design*

We conducted a retrospective study of WA Police Force recruit injury and physical performance databases from 2018 to 2021. A previous study of the WA Police Force recruit injury database described the epidemiology and burden of all injuries (Merrick et al., 2022). Our current study excluded upper limb, thorax and neck injuries as they were unlikely to be influenced by the risk factors of interest that were running-based cardiorespiratory fitness tests. Lower-limb and lumbosacral injuries were included to examine the influence of cardiorespiratory fitness and police-specific functional capacity on injury incidence.

### *Ethical approvals*

Ethical approval was obtained through the Edith Cowan University Human Research Ethics Committee (ID: 2021-02982-MURPHY) with industry approval obtained via the WA Police Force Research Governance division.

### *Setting*

Prior to joining the WA Police Force, applicants must pass initial screening tests, which consist of physical and psychological testing. Applicants who pass the screening process are then recruited and scheduled to participate in a six-month basic training program in the WA Police Force Academy (Joondalup, WA, Australia). This training program involves physical, operational, and empty hand training activities. Upon completion of the six-month academy training program, the police recruits graduate to become qualified, operational front-line WA Police Force officers.

All injuries requiring medical review with training modifications during the basic training program are recorded within the WA Police Force recruit injury database. Injuries are diagnosed by a network of general practitioners and physiotherapists who complete an injury record form that is provided to the WA Police Force and transcribed into the WA Police Force recruit injury database. Information recorded includes the injured recruit's squad, surname, injury diagnosis (e.g., tibial fracture), number of days into the training program the injury occurred, and the number of days the recruit completed modified training due to injury.

Physical performance measures, such as the beep-test or Physical Performance Evaluation (PPE) are recorded in a separate database (i.e., the WA Police Force recruit physical performance database). This database also contains data related to recruit age (stratified as between 18-29 years or greater than 30 years of age) and sex.

***Injury definition and categorization***

Our study reported injuries in accordance with the International Olympic Committee consensus statement on the methods for recording and reporting epidemiological data related to sport and physical activity injuries (Bahr et al., 2020). Injuries were defined as requiring modification from physical training following consultation with a medical practitioner or physiotherapist (time-loss injury definition). Data linkage was performed by a single study author (NM) to create a single dataset within Microsoft® Excel ® for Microsoft 365 MSO (Version 2201) from the WA Police Force recruit injury database and physical performance database. The process of coding the injury diagnoses to a specific area/region and tissue/pathology type were performed by a single author (NM). The specific injury area/ regions and tissue/pathology types were those recommended by the International Olympic Committee for epidemiological research in injury during sport/physical activity. Data linkage was piloted by two members of the research team that are physiotherapists with experience diagnosing musculoskeletal injuries (NM and MCM). Where recruits had sustained upper-limb, thoracic, or cervical injuries they were treated as un-injured for the purposes of our analysis. Where recruits had sustained multiple lower-limb and/or lumbosacral spine injuries only the first injury was included in the analysis.

Upper-limb, thoracic and cervical injuries were excluded from this study as their mechanism of injury was judged to be unlikely to be related to running-related cardiorespiratory fitness and may act as confounders to analysis. This may be viewed as a limitation as there is evidence suggesting that having a previous injury may increase the risk of subsequent injury. However, we chose only to examine index injuries in our analysis for pragmatic reasons, and therefore lacking a more nuanced analysis of subsequent injury risk, we purposely excluded injuries to areas other than the lower limb and back to provide more specific, and clinically relevant results.

***Cardiorespiratory fitness***

Cardiorespiratory fitness was assessed using the beep-test (Mayorga-Vega et al., 2015), which is a reliable and commonly used field-based test, due to the ease of its administration (Mayorga-Vega et al., 2015). Recruits are required to run 20m shuttles at increasing speeds in time with an external auditory pacer (Mayorga-Vega et al., 2015). The test continues until they are unable to complete the 20m shuttle in the time provided. Recruits are subsequently assigned a completion level, with a higher score representing greater cardiorespiratory fitness. The beep-test is performed upon commencement at the WA Police Force Academy, and two weeks prior to completion of the 28-week recruit training program.

***Police-specific functional capacity***

Physical performance evaluations (PPE) were used to assess police-specific functional conditioning. This is a timed test wearing full operational WA Police Force uniform and involves the completion of an obstacle course including components of agility, endurance, strength, balance, and speed, with the lower-limb and back experiencing the highest load. Recruits perform the PPE upon commencement at the WA Police Force Academy and two weeks prior to completion of the 28-week recruit training program. However, during the final PPE, recruits must also be equipped with full load carriage, meaning they now wear accoutrements and body armour when completing the course.

The PPE involves two laps of a 165m running track. The first lap is a sprint and the second lap includes performing a number of obstacles: Traverse a 6m long balance beam; scale and go over a 1.8m high fibre fence; scale and go over a 1.2m high brick wall; jump over the entirety of a 1.5m long sand-pit; hurdle over two 60cm high hurdles placed 5m apart; carry two 20kg kettlebells for 15m; climb through two windows at a height of 1.2m and 1.5m, respectively; scale and go over a 2.8m high cyclone fence; lift and carry a 40kg sandbag for 15m. As this is a unique, Police Force specific training task the reliability and validity has not been established, however the test has been in use for greater than ten years.

### *Missing data*

Recruit age and sex were requested directly from the WA Police Force when these records were not available within the initial databases provided. Where these data were unable to be provided, participants were excluded given the significant influence of these variables on injury incidence. A classification of 'unspecified' was assigned when details were unable to ensure accurate classification of a body area/region. A classification of 'non-specific' was assigned when details provided were inadequate to enable classification of a tissue/pathology type. Clinical judgement was used where information within the diagnosis could feasibly allow classification of the injury area/region or tissue/pathology type with classification agreed by consensus (NM/ MCM).

### *Data analysis*

Age, sex, beep-test, and PPE results were reported using descriptive statistics. We reported the injury area/region and tissue/pathology type using frequency and proportion. The overall injury frequency and prevalence were also reported. The assumptions of normality were met, hence paired t-tests were used to quantify change in the beep-test or PPE from baseline to the end of academy training. Multivariable binary logistic regression quantified the effect of sex, age, baseline beep test and baseline PPE score on the dichotomous outcome variables of lower-limb and lumbosacral injury occurrence reporting odds ratio (OR) and 95% confidence intervals (CI). Cases without baseline beep-test or PPE data were excluded from the multivariable analysis. Model fit was determined using the Akaike's Information Criterion (AIC) with lower values representing a better model fit. Cox proportional hazards regression time-to-event (survival) analysis examined injury risk over time, when accounting for sex, reporting OR and 95% CIs. Risk of injury probabilities were depicted using a Kaplan-Meier curve, separated for sex. IBM SPSS Statistics (version 28.0.1.0) was used for all data analyses with statistical significance set at $p<0.05$.

## Results

### *Participants*

A total of 1,181 WA Police force recruits were included. All participants completed their basic training between 2018-2021, entered recruit training without an injury, and had age and sex reported (Figure 1). Of the 1,181 included recruits, 725 (61.4%) recruits were between 18-29 years of age and 456 (38.6%) were aged ≥30 years with 819 (69.3%) recruits being male and 362 (30.7%) recruits being female.

### *Injuries*

Between 2018 and 2021, 180 recruits were recorded by the WA Police Force as having a lower-limb or lumbosacral injury, with 1,001 recruits not reporting a lower-limb or lumbosacral injury. Providing an injury period prevalence of 15.2% during the six-month training program.

***Lower-limb and lumbosacral injury area/region and tissue/ pathology type***

The frequency and proportion of lower limb and lumbosacral injuries by region/ area are presented in Figure 2. Knee followed by lower leg injuries were the most common injury area/region. The frequency and proportion of lower-limb and lumbosacral injuries by injury tissue/ pathology type is presented in Figure 2. Muscle or tendon injuries were the most common tissue/ pathology type.

***Change in physical fitness and police-specific functional capacity over the training program***

A significant within-group improvement in cardiorespiratory fitness (d= 0.31, 95%CI= 0.17 to 0.46, p<0.001) and police-specific functional capacity (d=-0.18, -0.33 to -0.04, p<0.001) were observed in recruits over the six-month WA Police Force recruit training program (Table 1).

***Relationship between baseline physical fitness and police-specific functional capacity and lower-limb and lumbosacral injury***

Multivariable binary logistic regression reported a non-significant effect for age, which on removal indicated an improved model fit (smaller AIC). The reported model (Table 2) determined that better baseline cardiorespiratory fitness was associated with a reduced risk of injury occurrence (OR= 0.80, 95%CI= 0.66 to 0.96, p=0.019). Risk of injury was almost double in males, compared to females (OR=1.940, 95%CI= 1.05 to 3.58, p=0.034), when accounting for baseline cardiorespiratory fitness. There was no associated risk detected between baseline police-specific functional capacity scores and injury occurrence (p=0.138), although a positive association was noted (OR=1.39, 95%CI= 0.90 to 2.14).

***Influence of days into training on lower-limb and lumbosacral injury risk***

Almost half of the sustained injuries occurred within the first 30 days of recruit training (47.2%), with a further 22.2% occurring in second 30 days of the recruit training program. Injury risk demonstrated a temporal trend towards a reduction in injury occurrence over time (p=0.020). Sex had a significant influence on injury rate (OR (95%CI) = 0.70 (0.52 to 0.95), p=0.021) with females sustaining injuries earlier in recruit training (Figure 3).

**Discussion**

Our study is the first to specifically explore physical risk factors for lower-limb and lumbosacral injuries in Police Force recruits. We found that approximately 15% of police recruits experienced a lower-limb or lumbosacral injury during their recruit training. Of the lower-limb and lumbosacral injuries included within this study, knees were the most frequently injured region (23%), and muscle/tendon injuries were the most frequent injury tissue/pathology type (36%). Our study also found increased cardiorespiratory fitness levels reduced injury risk, with every level higher on the beep-test a recruit scored at baseline being associated with a decreased risk of injury by 20%. No significant association with functional capacity was found. Female recruits were injured earlier within the recruit training program than males. These findings have clear clinical implications for policy and practice as they allow Police Force organisations to implement strategies specifically aimed at addressing these risk factors.

Our study supports existing literature that poor baseline cardiorespiratory fitness is a risk factor for lower-limb injury in law enforcement (Knapik et al., 2011; Lockie et al., 2019; Orr et al., 2020) and military recruit training program (Blacker et al., 2008; Jones et al., 2017; Müller-Schilling et al., 2019). However, the confidence intervals for the OR's in our study were relatively narrow with a small AIC model output, suggesting higher confidence in the relationship between cardiorespiratory fitness and injury than observed in previous studies. This may be due to our larger sample size or the use of specific injury regions as outcome measures, more likely to be related to running-related cardiorespiratory fitness. The baseline speed at which a recruit can perform police-specific skills (via an obstacle course) was not significantly associated with injury occurrence, however the large confidence intervals for the OR in the positive direction suggests further investigation is required with a larger sample size to disentangle potential police-specific skill components that may be associated with higher risk of injury, if at all. As the PPE involves a battery of strength, agility, and power production, if a recruit is deficient in one component they may make up for it in others, confounding results. It may be more accurate for injury surveillance purposes to time individual legs of the PPE (e.g., separate agility, strength and power tasks) to more accurately identify recruit physical impairments, relative to their peers. Therefore, by separating components of the PPE and performing other physical capacity variables that were not measured in this study, such as lower-limb strength, stronger associations to injury may be identified.

Our study reported that when accounting for cardiorespiratory fitness, males were over 90% more likely to be injured than females. These findings were unexpected, as with our previous research, and others, demonstrated an increased risk of injury in female Police Force recruits (Merrick et al., 2022; Parsons et al., 2021). This means that females were at a reduced risk of injury than males with an identical beep-test score. However, due to sex-based differences in maximal oxygen consumption, normative values for the beep-test are different for males and females (Santisteban et al., 2022). This means males who have an identical beep-test to females are likely to have poorer cardiorespiratory fitness and may explain the increased injury risk associated with being male in our study. Regardless, our findings are novel and differ to those seen in sporting or military populations, where females are typically injured at higher rates than males (Murphy et al., 2022b; Parsons et al., 2021). Furthermore, our study demonstrated that female recruits sustain injuries earlier within the recruit training program than males. The time to injury analysis we performed is novel in Police research, however the divergence seen in the Kaplan-Meier curve, with females being injured earlier than males has also been demonstrated in military recruits (Hearn et al., 2021). Further research is needed to understand why this injury divergence occurs.

Our study findings have important implications for recruit training programs. Interventions that increase the baseline cardiorespiratory fitness of recruits may have a protective influence on risk of injury during recruit training. A simple strategy to address this would be to increase the fitness standards for recruits applying to join the Police Force. However, this could exclude recruits who may excel in other components of recruit training. Additionally, changing these standards may limit diversity within the Police Force which is vital to a profession perpetually dealing with a diverse population (Miles-Johnson, 2019). Conditioning and injury prevention programs that can be delivered prior to training induction would allow recruit cardiorespiratory fitness levels to increase yet avoids precluding recruits from joining the Police Force solely based on fitness. Several different programs have been shown to improve conditioning in recruit populations and could be incorporated into prevention policy, as a bridging course prior to academy induction (Knapik et al., 2006; Kyröläinen et al., 2018; Lee et al., 1997).

***Future direction***

Future research should look to quantify the financial burden due to time-loss injury in Police recruits, as this will assist governing bodies in determining the cost-benefit ratio of providing financial resources to injury prevention without performing unnecessary and burdensome reporting demands on recruits (Murphy et al., 2021). Injury prevention trials, aiming to address the injuries associated with the highest time-loss burden (Merrick et al., 2022) (predominantly joint/ligament and muscle/tendon) and the risk factors we have identified in our study would also be of benefit.

***Limitations***

Whilst our regression model AIC was small and it correctly classified 87.1% of cases, it did not explain all the variance within the model and future research should consider including other components, such as muscle strength or biomechanics, as well as disentangle potential police-specific skill aspects that may be associated with injury. Coding errors may have occurred due to only a single author (NM) performing data linkage; we expect these to be minimal given two study authors (NM and MM) piloted the data linkage initially and the first author for this study (MM), has substantial experience in data extraction and management (Harris et al., 2021; Murphy et al., 2018, 2019, 2020). The missing demographic data were determined to be missing at random, and mirrors what is seen within other database studies (Brushøj et al., 2008; Everard et al., 2018; Fallowfield et al., 2020; Sharma et al., 2017).

**Conclusion**

More than one in seven police recruits experience a lower-limb or lumbosacral injury during their recruit training. Increased cardiorespiratory fitness levels were associated with a decreased risk of injury, with every level of the beep-test higher, associated with a 20% reduction in injury risk. When accounting for baseline fitness, males were more likely to be injured than females, while females tended to be injured earlier in the recruit training program than males. Interventions that can pre-condition Police Force recruits prior to the commencement of their basic physical training would likely reduce lower-limb and lumbosacral injuries. Additionally, monitoring early signs of injury in the female recruits, during the initial stages of Police Force recruit training may also reduce their number of injuries.

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Table 1. Within group change over time for physical fitness and police-specific functional capacity

| | n | Baseline, M (SD) | Follow-up, M (SD), n | Difference, M (SD) | t | Significance, p | Cohen's d (95%CI) |
|---|---|---|---|---|---|---|---|
| Beep test, Level | 751 | 9.5 (1.6) | 10.0 (1.6) | -0.4 (0.9) | -11.9 | <0.001 | 0.31 (0.17 to 0.46) |
| PPE, mins | 725 | 2.0 (0.6) | 1.9 (0.5) | 0.1 (0.4) | 6.1 | <0.001 | -0.18 (-0.33 to -0.04) |

Legend: M= mean, SD= standard deviation, n=number, t= test statistic

Table 2. Multivariable binary logistic regression assessing the effect of baseline physical fitness and police-specific functional capacity on lower-limb and lumbosacral injury occurrence adjusting for sex.

| Variable | β | Standard Error | p-value | Odd ratio (95%CI) |
|---|---|---|---|---|
| Baseline cardiorespiratory fitness | -0.23 | 0.10 | 0.019 | 0.80 (0.66 to 0.96) |
| Baseline police-specific functional capacity | 0.33 | 0.22 | 0.138 | 1.39 (0.90 to 2.14) |
| Sex (Male)[a] | 0.66 | 0.31 | 0.034 | 1.94 (1.05 to 3.58) |

Note β=beta coefficient; [a] compared to female; Model fit AIC=529 with the model accurately classifying 87.1% of cases.

Figure 1. STROBE flow chart demonstrating participant recruitment.

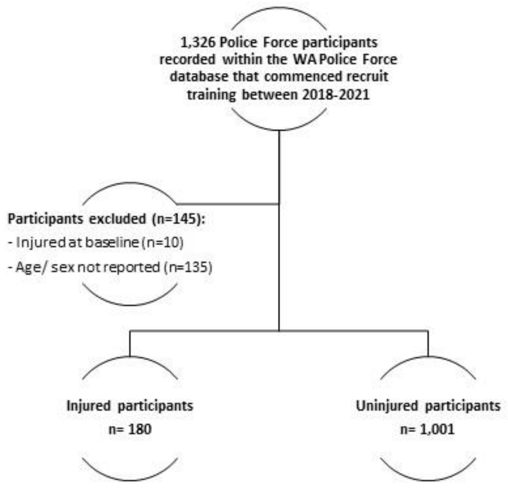

Figure 2. Left) The proportion (percentage) of different area/regions of lower-limb and lumbosacral injuries and, Right) the proportion (percentage) of different specific tissue/ pathology types of lower-limb and lumbosacral injuries.

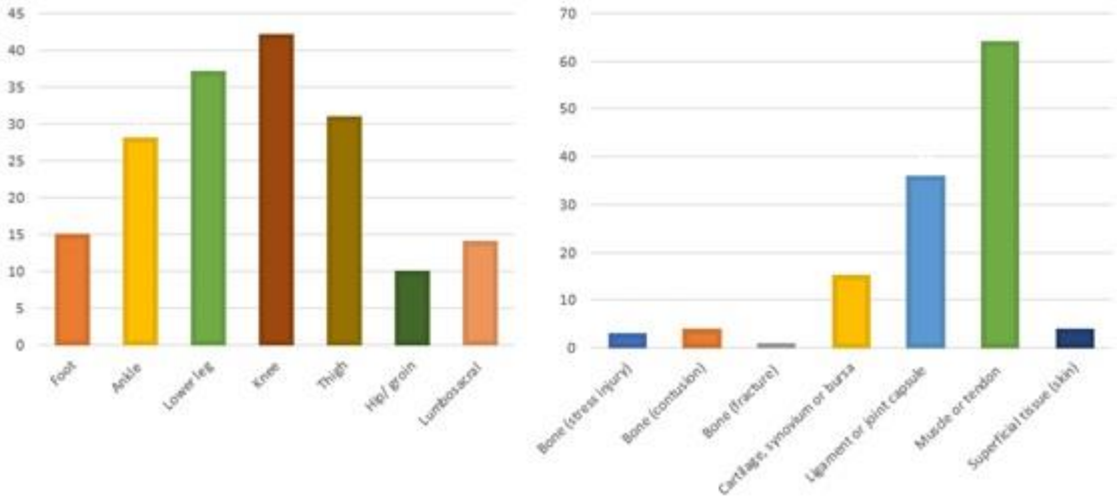

Figure 3. Injury probability based on days of training, split for sex: Cox-regression survival analysis