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# From control to causation: Validating a 'complex systems model' of running-related injury development and prevention

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A B S T R A C T

*Introduction:* There is a need for an ecological and complex systems approach for better understanding the development and prevention of running-related injury (RRI). In a previous article, we proposed a prototype model of the Australian recreational distance running system which was based on the Systems Theoretic Accident Mapping and Processes (STAMP) method. That model included the influence of political, organisational, managerial, and sociocultural determinants alongside individual-level factors in relation to RRI development. The purpose of this study was to validate that prototype model by drawing on the expertise of both systems thinking and distance running experts.
*Materials and methods:* This study used a modified Delphi technique involving a series of online surveys (December 2016- March 2017). The initial survey was divided into four sections containing a total of seven questions pertaining to different features associated with the prototype model. Consensus in opinion about the validity of the prototype model was reached when the number of experts who agreed or disagreed with survey statement was ≥75% of the total number of respondents.
*Results:* A total of two Delphi rounds was needed to validate the prototype model. Out of a total of 51 experts who were initially contacted, 50.9% (n = 26) completed the first round of the Delphi, and 92.3% (n = 24) of those in the first round participated in the second. Most of the 24 full participants considered themselves to be a running expert (66.7%), and approximately a third indicated their expertise as a systems thinker (33.3%). After the second round, 91.7% of the experts agreed that the prototype model was a valid description of the Australian distance running system.
*Conclusion:* This is the first study to formally examine the development and prevention of RRI from an ecological and complex systems perspective. The validated model of the Australian distance running system facilitates theoretical advancement in terms of identifying practical system-wide opportunities for the implementation of sustainable RRI prevention interventions. This 'big picture' perspective represents the first step required when thinking about the range of contributory causal factors that affect other system elements, as well as runners' behaviours in relation to RRI risk.


## 1. Introduction

On both a local and global scale, the sporting activity of distance running has been increasing in popularity over the last four decades. This is likely attributable to a growing societal concern around a documented rise in several lifestyle-related chronic diseases (Harold et al., 2016; Lee et al., 2017). As a form of exercise, recreational running provides significant beneficial effects on a range of biomedical health indices (Lee et al., 2014; Hespanhol et al., 2015), and is the preferred physical activity of choice for many people given its high accessibility and relatively low financial cost (Cregan-Reid, 2016). Furthermore, the growth associated with running-related festivals, ranging from charity-based events in regional communities to major annual marathons in some of the

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world's most iconic cities, is attracting both participants and large crowds of spectators (Strout, 2016). Notwithstanding the many health-related benefits that running offers to its regular adherents, the risk of sustaining a running-related injury (RRI) can be high. Depending on the ability level of the runner, the RRI incidence rate has been found to range from 2.5 to 33.0 injuries per 1000 h of running (Videbæk et al., 2015). Over a ≥12-month follow-up period, the time-loss injury incidence proportion in novice, cross-country, and long-distance runners has reportedly reached 84.9%, 77.4%, and 43.2%, respectively (Kluitenberg et al., 2015).

Over the last forty-five years, the science behind RRI causation and prevention has attracted considerable interest amongst sports injury researchers and scientists. During that time, there has been a concerted scholarly effort to understand the aetiology of RRI from an epidemiological and clinical research-based standpoint (Hulme and Finch, 2016). In fact, traditional scientific approaches have attempted to identify the effect of discrete training-related, behavioural, and/or biomechanical exposures on the risk of developing either general or specific RRI (Buist et al., 2010; Grau et al., 2011; Bredeweg et al., 2013; Malisoux et al., 2013; Nielsen et al., 2013). Typical training-related and behavioural exposures are related to running practice (e.g. weekly distance, duration, and frequency), diet, psychology, footwear, and terrain and surface (Hulme et al., 2016). On the other hand, biomechanical investigations cover a range of exposures relating to ground reaction force, range of motion, static limb measurement, and muscular strength and endurance (Zadpoor and Nikooyan, 2011; Newman et al., 2013; van der Worp et al., 2016). Despite this considerable body of work, several descriptive (Hoeberigs, 1992; van Mechelen, 1992; Hreljac, 2004; Ryan et al., 2006, Fredericson and Misra, 2007; Wen, 2007; Fields et al., 2010; Gingrich and Harrast, 2015) and systematic reviews (van Gent et al., 2007; Nielsen et al., 2012; Saragiotto et al., 2014; van der Worp et al., 2015; Hulme et al., 2016) have not been able to offer any compelling reasons for why runners sustain RRI.

There are many different reasons for why it has been difficult to identify aetiological mechanisms underpinning RRI. Given the time and space required to discuss those reasons, the reader is invited to review them elsewhere (Verhagen, 2012; Nielsen et al., 2014; Malisoux et al., 2015; Hulme et al., 2016; Nielsen et al., 2016). In this article, we argue for a complementary research approach that, alongside the continuing application of epidemiological and clinical research-based applications, will help to better understand the range of contributory causal factors that precipitate the development of RRI. More specifically, there is a current need to elucidate the many political, organisational, managerial and sociocultural processes that comprise the mediating pathways that influence runners' training-related and behavioural practices in relation to the development of RRI. To address this knowledge gap, and to complement traditional forms of scientific inquiry, this paper proposes the use of systems ergonomics research approach.

### 1.1. Applying systems ergonomics theory to RRI causation and prevention

Systems ergonomics is the study of 'sociotechnical systems' which examines the interactions between people, and a range of organisational and technological factors that influence their beliefs, decisions, and behaviours (International Ergonomics Association, 2016). By extension, the whole of society itself is one large sociotechnical system that is evolving at a rate dependant on the introduction of new procedures, knowledge, and technologies (Vicente and Christoffersen, 2006). Historically, the application of systems-based approaches was reserved for studying safety-critical domains as found in engineering and industrial work contexts, particularly in relation to improving employee well-being and optimising the performance of human-machine interactions (Walker et al., 2008; Wilson, 2014). Given the versatility and utility of these approaches for enhancing safety in other life domains (Holden, 2009; Salmon et al., 2012), scholars have recently offered compelling arguments for why otherwise 'simple' human-led physical activities are also taking place in systems that are both complex and sociotechnical in nature (Davis et al., 2014; Carden et al., 2017).

In one of our previous studies (Hulme et al., 2017), the Systems Theoretic Accident Mapping and Processes (STAMP) method (Leveson, 2004) was used to develop a prototype control structure model of the Australian recreational distance running system. The prototype model identified who might reside in the overall system (e.g. runners, athletic coaches and trainers, community allied health professionals, advocacy groups, and athletics governing bodies), as well as what 'control' and 'feedback' mechanisms might exist between them (Hulme et al., 2017). Its aim was to conceptualise that safe running practices and the management of RRI risk should be viewed as a 'control problem' that occurs when latent failures and disruptions to the normal functioning and operations across the distance running system are not adequately managed or monitored by its contained actors and organisations. The prototype model was primarily created to demonstrate the argument that systems ergonomics methods based on a systems-theoretic approach to accident analysis have much to offer to sports injury prevention research. Whilst the prototype model is useful from an ecological standpoint, there is a need to validate it to ensure that it accurately represents the system under investigation. Therefore, the purpose of this study was to draw on the expertise of both systems thinking and distance running experts to validate the prototype Australian distance running systems model.

## 2. Methods

This study used a modified Delphi technique whereby a panel of subject matter experts provided rounds of feedback on the content of a prototype Australian distance running systems model (hereby referred to as 'prototype model'). This study was approved by the Federation University Australia Human Research Ethics Committee (project number B16-180).

### 2.1. Creation of the prototype model

There are two main components associated with the STAMP method and its associated control structure: (i) system development (including both the development process itself and the resulting system design); and, (ii) system operation (which under ideal conditions, nurtures safe behaviours) (Leveson, 2004). Accordingly, the prototype model was constructed incrementally in the following stages: (i) the system operation component associated with the STAMP method was adapted to fit the target context; (ii) the actors and organisations who were considered to reside at each of the model's five different hierarchical levels were identified; and, (iii) the control and feedback mechanisms that were thought to exist between those levels were added.

Information derived across various sources facilitated the development process, including documentation related to recreational running (e.g. Athletics Australia), stakeholder websites (e.g. Australian Sports Commission), and the academic literature. In addition, the authors' own knowledge of the RRI domain (Hulme and Nielsen), and other authors' extensive experience in use of systems ergonomics methods (Salmon and Read) helped to further refine certain aspects. A more detailed description of the original STAMP method, including control theory and its adaption to the