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Linking psychological risk profiles to running-related injuries and chronic fatigue in long-distance runners: A latent profile analysis

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ABSTRACT

Introduction: Consistently predicting adverse outcomes of long-distance running, such as running-related injuries (RRIs) and chronic fatigue, has proven to be a complicated matter. However, research suggests that a stronger focus on psychological factors of runners might provide further insights. Consequently, in this study, we explored the interplay between self-regulatory coping strategies and motivational aspects. Using a person-centered approach, we investigated whether latent psychological profiles of runners were associated with RRIs and chronic fatigue.
Methods: Questionnaire data were gathered from Dutch recreational long-distance runners ($N = 425$) using a cross-sectional design. We determined whether specific psychological combinations (i.e., latent profiles) based on coping strategies (i.e., running-related resources and recovery) and motivational aspects (i.e., harmonious and obsessive passion) could be distinguished using latent profile analysis (LPA). The resulting profiles were tested for their associations with RRIs and chronic fatigue.
Results: LPA revealed three different psychological risk profiles, termed the 'low-risk', 'medium-risk', and 'high-risk' profile. The low-risk profile showed low scores on obsessive passion and high scores on all recovery dimensions, whereas the high-risk profile resembled the opposite pattern. Furthermore, the low-risk profile showed significantly fewer RRIs and lower chronic fatigue scores than the high-risk profile.
Discussion: The results reveal that (1) patterns of passion and coping strategies interact in defining different profiles and (2) that such profiles are indeed linked to RRIs and chronic fatigue. Utilizing profiles might enable targeted intervention and more effective preventative measures by pinpointing at-risk runners. Specific combinations of psychological aspects, as reflected by our profiles, thus appear a worthwhile direction to consider in understanding RRIs and chronic fatigue in long-distance running.

Recreational running has been linked to higher mental and physical functioning, better moods, reduced mortality rates, and improved mental health (e.g., Oswald et al., 2020; Pedisic et al., 2019; Roeh et al., 2020). Through improved fitness levels, running is also associated with longevity and promotes long-term exercise (Fields et al., 2010). These benefits, coupled with the low entry barriers, have attracted many people to recreational running, turning it into a globally popular sport (Pedisic et al., 2019; Scheerder et al., 2020). Yet, alongside these positive outcomes stands the potential for running to negatively affect runners' health and well-being through running-related injuries (van Poppel et al., 2020) and chronic fatigue (Kayser & Gremion, 2004; Sperlich et al., 2016).

Running-related injuries (RRIs) are prevalent in recreational running across countries (Videbæk et al., 2015). In the Netherlands, for instance, recreational runners incur 6.1 injuries per 1000 training hours, which is nearly double the average across all Dutch sports (i.e., 3.1 injuries on average; Stam & Valkenberg, 2019). RRIs might carry high personal and societal costs, including lower mental and physical health due to not being able to train, suffering from pain, pressure on health care, absenteeism, and long periods to reach full recovery (e.g., Hespanhol Junior et al., 2016; Morgan et al., 2018). Long-distance running (i.e., half and whole marathon distances) appears to potentially increase RRI risk even further, with some studies reporting higher RRI incidence rates among those running longer distances (e.g., van Poppel et al., 2018).

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Recreational runners may also suffer from *chronic fatigue*, which can be defined as severe and long-lasting mental and physical exhaustion (Michielsen et al., 2004). In contrast: *transient* fatigue is a common and normal consequence of physical and mental work demands from which one recovers quickly after rest and which has minimal impact on quality of life (Hornsby et al., 2016). However, the transient nature of fatigue may turn chronic when one consistently pushes running efforts too far while recovering insufficiently. The resulting chronic fatigue may cause a variety of adverse conditions, such as mood disturbances, muscle soreness and stiffness, trouble sleeping, motivation issues, hormonal imbalances, immune suppression, and performance reduction (Olson et al., 2018). Studies on similar conditions show that chronic fatigue can result from a sustained imbalance between load and load capacity. This is evidenced in overtraining syndrome (Kreher & Schwartz, 2012), which affects 33% of recreational runners over their career (Meeusen et al., 2013), and athlete burnout (Lopes & Vallerand, 2020).

In this study, we aim to advance the understanding of psychological factors linked to RRIs and chronic fatigue in recreational long-distance runners. Generally, studies on RRIs and fatigue focus on physical or biological training characteristics as determinants, such as body composition, age, nutrition, strength training, running distance, running frequency, and running shoes (e.g., van Poppel et al., 2020). Although less often investigated, psychological determinants of RRIs and chronic fatigue are likely a worthwhile and necessary addition to physical and biological perspectives (e.g., Fields et al., 2010; Nielsen et al., 2020; Truong et al., 2020; von Rosen et al., 2017; Wiese-Bjornstal, 2018). In the current paper, we expand on two proposed psychological factors thought to be linked to RRIs and chronic fatigue: (1) self-regulatory behavior, as indicated by the employment of coping strategies (e.g., adequate recovery and resource usage; de Jonge et al., 2018; van Iperen et al., 2020), and (2) passion for running (de Jonge et al., 2020; Stephan et al., 2009). More specifically, we aim to explore whether so-called latent risk profiles based on these psychological factors are associated with RRIs and chronic fatigue in recreational long-distance runners.

Expanding on etiology and determining which runners are most at risk of RRI and chronic fatigue, this research has important implications for theory and practice. Establishing the combined role of coping strategies and passion in relation to RRIs and chronic fatigue would corroborate the theoretical relevance of psychological factors in long-distance runners. Any such insights will aid the design and implementation of preventative measures (e.g., de Jonge et al., 2018), which can potentially reduce the occurrence of the mentioned issues, reducing associated individual, organizational, and societal costs (e.g., Hespanhol Junior et al., 2016) and enabling recreational runners to more sustainably continue their sport (e.g., Menheere et al., 2020).

1. Psychological predictors of running-related injuries and chronic fatigue

In lieu of many studies on the topic, a previous RRI remains the strongest predictor of new RRIs in long-distance runners (e.g., van Poppel et al., 2020). Although the commonly employed physical and biological approaches are essential, a wider research lens encompassing psychological perspectives (e.g., Olson et al., 2018; Thompson et al., 2020) could strengthen our understanding of the etiology of RRIs and chronic fatigue in runners. For sports injuries in general, some studies already highlight examples of predictive psychological factors, such as personality, coping, and stress responses (Ivarsson et al., 2016; Weinberg & Gould, 2019). However, specific evidence of psychological factors predicting RRIs and chronic fatigue in runners remains relatively scarce. There is some evidence for the role of motivation and specific psychological running profiles in RRIs (e.g., Christensen & Ogles, 2017; Martin et al., 2021), and recently Cadegiani (2020) described psychosocial and behavioral aspects associated with exhaustion (cf. chronic fatigue) in endurance sports. Yet, psychological factors that may give rise to these issues are but occasionally empirically tested. This knowledge gap on psychological predictors of RRIs and chronic fatigue is all the more relevant, given the many psychological and social aspects that are known to predict athletes' health and well-being (e.g., Downward & Rasciute, 2011; van Iperen et al., 2020).

2. Running-related injuries and chronic fatigue: A self-regulation perspective

In this study, we employ a *self-regulation perspective*, which refers to how runners change their own responses or inner states in a goal-directed fashion (McCormick et al., 2018). To approach or avoid specific states or goals, a runner must engage in self-regulatory behavior, such as deciding how much effort to put into running and whether and how to employ coping strategies to deal with their efforts (de Jonge et al., 2018; McCormick et al., 2018). These efforts, collectively termed running-related demands, encapsulate both physical and mental (i.e., cognitive and emotional) efforts put into running (de Jonge et al., 2018), such as bodily exertion, emotional stress, and continued focus (van Iperen et al., 2020). Studies have also highlighted strategies for adequately coping with these running-related demands, similarly differentiated in physical and mental aspects (Balk, 2018). These include the employment of running-related resources (e.g., support from running colleagues) and recovery from running (e.g., mental detachment after training), both of which have proven to be effective coping strategies (e.g., van Iperen et al., 2020).

How runners engage in functional self-regulation and associated coping behaviors is fundamental in psychological models predicting both acute RRI vulnerability (e.g., Williams & Andersen, 1998) as well as overuse RRI vulnerability (e.g., Tranaeus et al., 2014). However, the mechanism behind both types of RRIs differs. An acute RRI results from a sudden and traumatic event, whereas an overuse RRI results from the buildup of repetitive micro-traumas over time (Bahr et al., 2020; Tranaeus et al., 2014). In this paper, we generally refer to both types of injuries when describing (overall) RRIs, unless otherwise specified. In line with the highlighted importance of self-regulation for RRIs , Hagger et al. (2009) have proposed that failure to self-regulate instigates many health-related issues, further differentiating three types of self-regulation failure. First, a lack of self-regulation, or '*underregulation*', such as a runner who trains very inconsistently and thereby prevents adequate adaptation to the strain of running. Second, an excess of self-regulation, or '*overregulation*', in which case we may imagine a runner who strictly follows a running schedule in spite of an aching knee, thereby exacerbating an impending injury. Finally, a misdirection of self-regulation, or '*misregulation*', in which case, for example, runners self-regulate their running behavior but not in the right manner or moment. Thus, if sport demands are not adequately regulated (e.g., by not sufficiently employing coping strategies; Balk, 2018; de Jonge et al., 2018; Kellmann et al., 2018), the resulting stress may increase the risk of overuse injury and chronic fatigue (cf. Tam et al., 2017; van der Sluis et al., 2019).

Failure to self-regulate can occur due to a variety of reasons. Often mentioned is the depletion aspect, as self-regulation is, in and of itself, "a limited resource that is expended when people engage in behaviors that require self-control" (Hagger et al., 2010, p. 63). This mechanism resembles muscle contraction, as continuous usage diminishes performance (Hagger et al., 2009). Decision-making is impaired upon depletion of this resource and may thereby impair self-regulation, which has been suggested to be associated with motivational aspects in non-sport contexts (cf. Bélanger et al., 2013). Beyond depletion, motivational aspects may also predict inadequate self-regulation (e.g., Lucidi et al., 2016). For example, the type and strength of passion for a certain activity, such as sports, has been shown to predict the selection and application of coping strategies (Verner-Filion et al., 2014). Indeed, evidence for this relation was found in a recent study on mental recovery and passion for running in the prediction of overall RRIs in recreational runners (de Jonge et al., 2020). Based on these findings, we expect that certain types of passion for running may impair a runner's ability to adequately employ the correct coping strategies to deal with running-related demands. In doing so, we thus aim to determine whether RRIs and chronic fatigue are associated with motivational factors (i.e., passion for running) and self-regulatory behavior (i.e., employment of adequate coping strategies), both of which are discussed in-depth in the following sections.

3. Self-regulatory coping strategies for running-related demands

Two self-regulatory coping strategies have been proposed to describe how runners counterbalance their running-related demands (Balk, 2018; de Jonge et al., 2018; Kellmann et al., 2018; van Iperen et al., 2020): (1) adequate employment of running-related resources and (2) adequate recovery from running efforts. First, employing *running-related resources* as a coping strategy refers to adequately utilizing the contextually available means or assets through which runners can experience control over and social support in dealing with running-related demands. Examples include control over training intensity, and support from teammates (de Jonge et al., 2018). Resources are assumed to buffer the impact of running-related demands and thereby prevent adverse outcomes (Balk, 2018). Illustrating their importance, empirical studies have shown that a high demand-low resource condition was related to less emotional energy (Balk, 2018), more athletic injuries (Williams & Andersen, 1998), and more athlete burnout (Raedeke & Smith, 2004). In addition, a qualitative study on athletes from various sports indicated that social and emotional support were important self-regulatory strategies used in managing stress and physical and mental fatigue (Cosh & Tully, 2015).

Second, adequate *running-related recovery* as a coping strategy refers to the multifaceted process by which runners restore the baseline levels of the systems that were utilized during the sport-related physical and mental efforts (Kellmann et al., 2018). Consequently, running-related recovery is crucial in preserving runners' health and performance and is thus considered an integral part of long-distance running (de Jonge et al., 2018). For example, recovery from running was found to moderate the demands-energy relation in long-distance recreational runners (van Iperen et al., 2020). In more general athlete samples, higher recovery was found to be related to lower physical and mental fatigue (Cosh & Tully, 2015) and higher mental energy (Balk, 2018). Both physical and mental recovery from running-related activities are assumed to be important for adequate and complete recovery from sport (Balk, 2018; de Jonge et al., 2018). Insufficient recovery makes runners vulnerable to RRIs and chronic fatigue, as this prevents their utilized systems from properly restoring (Balk, 2018; Balk & Englert, 2020; de Jonge et al., 2020; Kellmann et al., 2018). Additionally, in case of mismanaged recovery, fatigue may develop that could impair runners' performance (van Cutsem et al., 2017). Hence, employing adequate recovery from running in relation to training efforts is crucial for avoiding RRIs and chronic fatigue.

4. Passion for running

Based on our functional self-regulation perspective, we further propose that whether or not runners counterbalance their running-related demands by means of running-related resources and recovery depends on their *passion for running* (de Jonge et al., 2018; Stephan et al., 2009; Verner-Filion et al., 2014). Passion can be defined as a strong inclination toward a specific activity (i.c., running) that "one loves (or at least strongly likes), highly values, invests time and energy in on a regular basis, and that is part of one's identity" (Vallerand, 2015, as cited in Vallerand & Verner-Filion, 2020, p. 33). Two types of passion can be distinguished in terms of how the passionate activity is internalized into one's core self (Vallerand & Verner-Filion, 2020). *Harmonious passion* results from autonomous internalization and concerns a personal state in which the runner feels engaged with running but —fundamentally—remains in control. It is harmonious with other aspects of oneself and one's life and is proposed to relate to adaptive outcomes such as higher well-being (Vallerand, 2010). *Obsessive passion* can be described as a personal state in which the runner feels compelled to engage in running and loses control over this desire. This results from a controlled internalization caused by intrapersonal or social pressure or by a lack of control over excitement for the activity (Verner-Filion et al., 2014). Consequently, obsessive passion may conflict with other aspects of oneself and one's life and is generally presumed to lead to less adaptive, or even maladaptive, outcomes on personal and interpersonal levels, such as injury susceptibility (Vallerand, 2010).

We expect both forms of passion to relate to the selection and efficacy of specific self-regulatory coping strategies in running. It should be noted that even though harmonious passion tends to relate to more adaptive outcomes and obsessive passion to more maladaptive ones (Curran et al., 2015), neither type of passion is intrinsically 'good' or 'bad'. In specific contexts, such as performing under pressure, obsessive passion has the potential to be functional (e.g., Vallerand & Verner-Filion, 2020). However, obsessive passion can indeed also be harmful to athletes. It has, for example, been associated with unhealthy (over-)training habits and exercise dependence, as found in a study on a variety of athletes (Paradis et al., 2013). In competitive runners, obsessive passion was linked to higher levels of perceived overall injury susceptibility, whereas harmonious passion showed the opposite pattern (Stephan et al., 2009). In studies on dancers, obsessive passion was positively associated with injury-related risky behavior and risk of chronic injuries (Akehurst & Oliver, 2013; Rip et al., 2006), whereas harmonious passion was negatively associated with acute injuries (Rip et al., 2006). Harmonious passion has also been negatively associated with burnout in athletes (Lopes & Vallerand, 2020), which encompasses the same type of exhaustion as chronic fatigue. Furthermore, Vallerand and Verner-Filion (2020) argues that harmonious passion enables adaptive self-regulation processes (see also Curran et al., 2015), such as an open-minded and flexible approach towards one's activity. Moreover, we envision that harmonious passion may also aid primary appraisal in self-regulation processes (cf. Folkman et al., 1986), thereby allowing athletes to more accurately appraise demands that exceed capacity, as well as in employing more suitable coping strategies. Against this background, we formulate our first proposition that harmonious passion for running is positively associated with the employment of adequate running-related coping strategies and thereby associated with lower risks of RRIs and chronic fatigue (see also Stephan et al., 2009).

Conversely, obsessive passion is expected to relate to deficiencies in self-regulation processes (e.g., Stenseng et al., 2011). This may explain the apparently harmful nature of obsessive passion, as it is proposed to hinder the adequate application of coping strategies and thereby increase injury risk and fatigue. For example, obsessive passion has been described as a defensive, ego-invested, and avoidance-oriented approach to coping strategies (Verner-Filion et al., 2014), which likely inhibits adequate responses to situations where training demands exceed training capacity. The link between passion for sport and self-regulation has also been tested by Stenseng et al. (2015), showing that in cyclists, obsessive passion was associated with an imbalance between ideal self (i.e., personal goal state) and ought self (i.e., perceived normative state). This is taken as an indication of poor self-regulation, contrasting with harmonious passion, which did not exhibit such patterns. Similarly, Stenseng et al. (2011) showed that obsessive passion was related to self-regulation deficiency in a study with general athletes. This suggests a link between obsessive passion and underregulation rather than overregulation. Based on these findings, our second proposition is that obsession passion for running is negatively associated with the employment of adequate running-related coping strategies, such as running-related resources and recovery, thereby being associated with higher risks of RRIs and chronic fatigue.

5. The present study

In this study, we explore the proposed interplay between self-regulatory running-related coping strategies and passion for running in their association with RRIs and chronic fatigue, employing a person-centered approach (i.e., focus on individuals and their naturally occurring profiles) as recommended by Soligard et al. (2016) and Nielsen et al. (2020). We test whether distinct latent psychological risk profiles based on running-related resources, running-related recovery, and obsessive and harmonious passion for running can be differentiated and, if so, whether these risk profiles are linked to RRIs and chronic fatigue in a sample of recreational long-distance runners. Given the exploratory nature of differentiating latent profiles, our investigation is non-confirmatory in that it builds upon the earlier established propositions and predicted patterns but does seek to empirically test explicit hypotheses (see Scheel et al., 2020).

6. Methods

6.1. Study procedure and sample

In this study, online cross-sectional survey data were gathered in 2018 as baseline data of a larger study, focusing on recreational long-distance runners (i.e., half and full marathon runners). Participants were gathered via (1) e-mails to participants of a recreational running event in the South of the Netherlands who volunteered for running-related research ($n = 307$); (2) e-mails sent out to the 20 largest running organizations in the Netherlands ($n = 78$); and (3) via five Dutch social media running groups ($n = 74$). This study adhered to the ethical principles of the Declaration of Helsinki and the American Psychological Association, and a Medical Research Ethics Committee waived our study from the ethical approval process. Participants gave informed consent for participation, receiving written information on confidential data treatment, the aim and conditions of the study, and requirements for participation rewards (i.e., a voucher and activity tracker lottery).

Our final sample comprised 425 recreational long-distance runners (i.e., training half and whole marathon distances), of which 57.2% were men and 42.8% were women, with a mean age of 44.7 years ($SD = 11.7$). Of the participating runners, 28.5% had a high school or vocational education, 40.7% had a bachelor's degree, and 30.8% had a master's or Ph.D. degree.

6.2. Measurements

Concerning demographics, participants were asked to report their gender (0 = male, 1 = female), age (years), and education (ranging from 1 = primary school to 9 = PhD).

Running-related resources were measured with the DISQ-SPORT 1.0, which was adapted for running (Balk, 2018). Participants were asked to rate how often items applied to their running sport using nine items on a scale from 1 ("*never*") to 5 ("*almost always*"). These nine items were distributed equally across physical resources ("*I have the opportunity to take a physical break when things get physically strenuous*"), cognitive resources (e.g., "*I have the opportunity to determine my own training method*"), and emotional resources (e.g., "*I get emotional support from others (e.g., from teammates) when an upsetting situation occurs*"). A confirmatory factor analysis (CFA) indicated that one item of cognitive resources (i.e., "*I have access to information (e.g., from the internet, books, files, meetings, clinics) to solve complex tasks*") needed to be dropped due to a lower factor loading ($\beta = 0.28$) and unsatisfactory reliability. Afterwards, one intra-factor correlation was allowed between two physical resources items, resulting in an acceptable model fit: $\chi^2(df = 16) = 41.689$, $p = <.001$, CFI = 0.986, TLI = 0.976, RMSEA = 0.061, SRMR = 0.050. Reliability (i.e., coefficient omega; McDonald, 1999) was satisfactory to good for physical ($\omega = 0.76$), cognitive ($\omega = 0.81$), and emotional resources ($\omega = 0.92$).

Recovery from running is conceptualized as detachment, referring to a reduction or cessation of physical, cognitive, and emotional involvement in a sport after training. It was measured by adapting the DISQ-R SPORT 1.2 to running, based on the scales developed by de Jonge et al. (2012) and formulated to the context of sports (Balk, 2018; van Iperen et al., 2020). Participants were asked to rate how often items applied to them after running on a scale from 1 ("*never*") to 5 ("*always*"). The measure consisted of 15 items, distributed equally across physical detachment from running (e.g., "*I get a break from the physical demands that my sport places on me*"), cognitive detachment from running (e.g., "*I think about other things than my sport activities*"), and emotional detachment from running (e.g., "*I put all emotions from my sport activities aside*"). A CFA showed that the item "*I physically relax from my sport efforts*" belonging to physical recovery underperformed in terms of factor loading ($\beta = 0.31$) and was therefore dropped. Model fit was acceptable only after allowing several intra-factor correlations, indicating potential problems with the proposed factor structure: $\chi^2(df = 62) = 188.791$, $p = <.001$, CFI = 0.957, TLI = 0.937, RMSEA = 0.069, SRMR = 0.036. The reliability of physical recovery ($\omega = 0.61$) was somewhat low but deemed acceptable for our purposes, cognitive recovery ($\omega = 0.69$) scored sufficiently, and emotional recovery ($\omega = 0.78$) performed satisfactory to good.

To measure both harmonious and obsessive passion for running, we used the validated Dutch version of Vallerand's (2010) passion scales (van der Knaap & Steensma, 2015), which we adapted to specify "*running*" rather than "*this activity*". Participants rated seven items per type of passion on a scale from 1 ("*not applicable to me*") to 7 ("*very strongly applicable to me*"). After allowing several intra-factor correlations, the CFA indicated an acceptable model fit: $\chi^2(df = 46) = 87.696$, $p = <.000$, CFI = 0.984, TLI = 0.978, RMSEA = 0.046, SRMR = 0.049. Both harmonious passion for running (e.g., "*My running sport is well integrated in my life*"; $\omega = 0.67$) and obsessive passion for running (e.g., "*I have difficulties controlling my urge to do my running sport*"; $\omega = 0.85$) were sufficiently reliable.

Participants were asked to self-report if they had been injured as a result of running in the past 12 months (0 = "*no*", 1 = "*yes*"). A running-related injury (RRI) was defined as "*any injury or bodily damage (whether or not paired with pain) which originated during running and which caused them to change their running activities*". Such changes referred to reducing the duration, speed, frequency, distance, and/or intensity of running activities or temporarily stopping entirely. This approach largely resembles the RRI definition proposed by Yamato et al. (2015). This broad definition, encompassing both acute and overuse injuries (see Bahr et al., 2020), suits the purpose of our study and increases statistical power as it captures more injuries (Nielsen et al., 2020).

The measure of chronic fatigue was adapted from the Fatigue Assessment Scale (Michielsen et al., 2004). Participants were asked to rate to what degree items applied to them on a scale from 1 ("*never*") to 5 ("*always*"). We used all original items, but to align with the physical-cognitive-emotional division of constructs in this paper, we split "*Mentally, I feel exhausted*" into "*Cognitively, I feel exhausted*" and "*Emotionally, I feel exhausted*", resulting in a total of 11 items. After allowance of several inter-item correlations, the CFA showed an acceptable model fit: $\chi^2(df = 38) = 98.024$, $p = < .001$, CFI = 0.971, TLI = 0.958, RMSEA = 0.061, SRMR = 0.037. Reliability was good ($\omega = 0.85$).

6.3. Analysis

6.3.1. Descriptives and psychometric testing

We calculated means, standard deviations, and zero-order correlations using IBM SPSS (Version 26.0). Reliability tests and confirmatory factor analyses were performed in Mplus (Version 8.4), adhering to the standards set out by Hair et al. (2019) to assess the model fit.

6.3.2. Latent profile analysis

We used *Latent Profile Analysis* (LPA) to explore underlying hidden groups (i.e., latent profiles) based on a chosen set of observed psychological indicators. The latent profiles in LPA refer to naturally occurring interactions (or: combinations) of indicator variables, which in turn can be tested in relation to outcomes (i.e., RRIs and chronic fatigue in runners). Thereby LPA allows us to consider psychological profiles of individuals based on a variety of indicators, which, when combined with their respective links to risk of RRIs and chronic fatigue, allow for the generation of risk profiles. This approach avoids some of the shortcomings of focusing on individual factors in a more reductionistic fashion (see Ivarsson & Stenling, 2019). Furthermore, LPA aligns with the complexity paradigm, which has been recommended to better understand risk for sports injuries (see Bittencourt et al., 2016; Ivarsson & Stenling, 2019; Wiese-Bjornstal, 2018) and which has been used extensively in sports context (e.g., Lindwall et al., 2017; Magee et al., 2016; Martin et al., 2021; Wang et al., 2016). LPA thereby allows us to add to the current empirical literature by determining which psychological (risk) profiles exist in runners and how these are related to RRIs and chronic fatigue.

In LPA, profiles beyond the first are incrementally estimated. A variety of decision criteria is then used to determine the best-fitting number of profiles (Ferguson et al., 2019). We performed a literature review to determine the most adequate decision criteria, resulting in: statistical adequacy (i.e., model convergence; Wang et al., 2016); interpretability and theoretical support (Ferguson et al., 2019; Lindwall et al., 2017); information criteria (i.e., lower scores imply better fit and elbow plots can be employed if a better fit is perpetually indicated; Ferguson et al., 2019; Wang et al., 2016); χ^2 difference tests (i.e., significant scores imply a better fit than the k - 1 profile; Ferguson et al., 2019), smallest group size (i.e., groups smaller than 5–8% are generally undesirable; Nylund-Gibson & Choi, 2018), group probability (i.e., >80% indicates high classification accuracy; Geiser, 2013). Finally, we report how clearly profiles are separated (i.e., general entropy) and the informativeness of an indicator in identifying profiles (i.e., univariate entropy; Asparouhov & Muthén, 2018).

LPA was performed in Mplus (Version 8.4) using the Robust Maximum Likelihood estimator, which is robust against non-normality. To assure that the most accurate loglikelihood value (i.e., to avoid converging at a local solution; a false maximum likelihood) and model estimations were obtained, we increased all Mplus default numbers of random starts, iterations, and optimizations by a factor 1000 (e.g., 100,000 iterations for 20,000 starts). Power in LPA depends less on sample size and more on profile characteristics, which cannot be estimated a priori in the case of new theoretical frameworks such as ours (Ferguson et al., 2019). For that very reason, we followed recent recommendations in evaluating power, finding that simulation studies show sample sizes exceeding 300 people are likely to suffice (Nylund-Gibson & Choi, 2018). We proceeded by estimating one profile and iteratively added profiles until we reached either 20 profiles or until solutions no longer proved statistically adequate (e.g., local solutions or negative variance estimates). These profiles were generated based on the following indicator variables: harmonious passion; obsessive passion; physical resources; cognitive resources; emotional resources; physical recovery; cognitive recovery; and emotional recovery.

After determining the adequate number of profiles based on the aforementioned criteria, we determined the relation between these profiles and auxiliary outcomes (i.e., RRIs and chronic fatigue). We used the BCH method for the continuous outcome chronic fatigue and Lanza's method for the categorical outcome RRIs, per the recommendations of Asparouhov and Muthén (2020). Effect size conversions were performed using the methods as outlined by Lenhard and Lenhard (2016).

7. Results

7.1. Descriptives and correlations of the key variables

Table 1 presents an overview of means (*M*), standard deviations (*SD*), reliabilities, and Pearson zero-order correlations of unstandardized variables. Many associations were intuitive (e.g., between dimensions of resources or recovery), yet others were intriguing. For instance, age was positively associated with all types of recovery and negatively related to chronic fatigue. In terms of self-reported RRIs, 59.8% of all runners in our sample reported having had an RRI in the past 12 months, a rate that aligns with comparable studies (e.g., van Poppel et al., 2020).

7.2. Latent psychological profiles

We started our analysis by iteratively adding profiles until statistical adequacy was no longer obtained, which occurred beyond 14 profiles. We reviewed decision criteria for all solutions as listed in Table 2, reporting only the first eight profiles for the sake of conciseness. In this multifaceted approach of determining the optimal number of profiles, we considered several solutions and came to three main findings. First, the BLRT, AIC, and SABIC all perpetually favored more profiles up to the non-sensical limit of 14 profiles, which can occur in LPA (cf. Wang et al., 2016). They were therefore considered non-informative and disregarded. Second, the combined results of the LMRA (i.e., significantly better fit than $k - 1$ profiles; Ferguson et al., 2019), elbow plotting of the CAIC and BIC (i.e., where the sharpest bends occur; Wang et al., 2016), and undesirable groups (i.e., below 5–8% of the sample; Nylund-Gibson & Choi, 2018) favored the 3-profile solution. Third, the raw CAIC and BIC score showed some support for the 5-profile and 7-profile solution, respectively. However, these solutions generated undesirably small groups while consisting mainly of the same profiles that were also found in the 3-profile solution (i.e., 5-profile solution = 90.0%; 7-profile solution = 72.8%). They, therefore, arguably indicated 'overextracted' versions of the 3-profile solution (Nylund-Gibson and Choi, 2018). With most decision criteria already pointing towards three profiles, the better interpretability and theoretical alignment were the final reasons for definitively selecting the 3-profile solution.

7.2.1. The 3-profile solution

The 3-profile solution offers adequately large and differentiated groups with interpretable differences (see Fig. 1). For clarity in referrals and based on their relations to outcomes, we term these profiles according to their risk, as discussed in the next subsections. Profile 1 (17% of sample), henceforth referred to as the *low-risk profile*, appears to consist of runners scoring low on obsessive passion and high on physical, cognitive, and emotional recovery. Profile 2 (62% of sample) seems to portray the very average majority and is termed the *medium-risk profile*. Profile 3 (22% of sample), called the *high-risk profile*, almost exactly mirrors the low-risk profile, scoring high on obsessive passion, and low on physical resources and all types of recovery.

In reviewing detailed results, we note that univariate entropy (see Table 3) is highest among the three types of recovery, thereby proving the most informative in discerning the latent profiles. In contrast, harmonious passion, cognitive resources, and emotional resources all play relatively minor roles, as they have the lowest univariate entropy and do not significantly relate to profiles.

7.2.2. Relation with running-related injuries

We found notable differences between profiles in terms of their RRI incidence (see Table 3). Specifically, the low-risk profile had the lowest chance of RRIs at 47% (*OR* = 1.000, reference profile), followed by the medium-risk profile at 59% (*OR* = 1.609, *LLCI* = 0.831, *ULCI* = 3.116), and the high-risk profile carried the highest chance of RRIs at 71% (*OR* = 2.684, *LLCI* = 1.286, *ULCI* = 5.603). Further analyses revealed that the overall test for differences in RRIs between profiles was significant

Table 1
Descriptives and pearson zero-order correlations (N = 425).

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Gender	0.43	0.50	(–)											
2. Age	44.66	11.74	-.23 *	(–)										
3. Education	6.17	1.66	.13 *	−08	(–)									
4. Obsessive passion	2.42	1.14	-.06	<.01	.02	(.85)								
5. Harmonious passion	5.20	0.86	.13 *	<.01	.09	.17 *	(.67)							
6. Physical resources	3.90	0.92	.11 *	-.01	.13 *	-.28 *	.04	(.76)						
7. Cognitive resources	4.27	0.78	.06 *	-.06	.05	-.16 *	.02	.48 *	(.81)					
8. Emotional resources	3.29	1.24	.19 *	.03	.16 *	-.04	.20 *	.29 *	-.02	(.92)				
9. Physical recovery	3.87	0.64	-.03	.20 *	.02	-.16 *	.16 *	.20 *	.10 *	.10 *	(.61)			
10. Cognitive recovery	3.45	0.72	.01	.23 *	-.01	-.27 *	-.02	.25 *	.08	<.01	.49 *	(.69)		
11. Emotional recovery	3.60	0.80	-.01	.28 *	-.03	-.22 *	.07	.24 *	.07	.08	.54 *	.72 *	(.78)	
12. Chronic fatigue	2.12	0.53	.14 *	-.19 *	.13 *	.18 *	-.13 *	.03	-.06	-.02	-.13 *	-.06	-.16 *	(.85)
13. RRI	0.60	0.49	-.05	.02	<.01	.16 *	.06	.01	<.01	<.01	-.04	-.08	-.10 *	.13 *

Note: For gender 0 = male and 1 = female; Education ranges from 1 (primary school) to 9 (PhD); RRI = Running-Related Injury in the past 12 months, with 0 = no and 1 = yes; Coefficient Omega is displayed on the diagonal; $^*p < .05$

Table 2
Fit statistics and decision criteria of all profile solutions.

Profiles	*DF*	SCF	LL	BIC	SABIC	AIC	CAIC	LMRA	BLRT	SGP	NG < 8%	LCP	Entropy
1	16	1.137	−4824	9746	9695	9681	9794	–	–	–	–	–	–
2	25	1.251	−4643	9438	9358	9336	9513	≤.001 *	≤.001 *	30.49%	0	86.9%	0.775
3[a]	**34**	**1.257**	−4574	9354	9246	9217	9457	**≤.014 ***	**≤.001 ***	**16.52%**	**0**	**80.4%**	**0.810**
4	43	1.446	−4519	9298	9162	9124	9428	≤.421	≤.001 *	6.39%	1	85.8%	0.829
5	52	1.538	−4460	9234	9069	9023	9391	≤.427	≤.001 *	3.00%	2	81.1%	0.826
6	61	1.383	−4422	9214	9020	8967	9398	≤.161	≤.001 *	2.71%	2	77.4%	0.826
7	70	1.263	−4394	9212	8990	8929	9424	≤.172	≤.001 *	2.79%	3	80.2%	0.862
8	79	1.240	−4371	9221	8970	8901	9460	≤.404	≤.001 *	1.04%	3	80.5%	0.869

Note: N = 425; *DF* = Degrees of Freedom; SCF = Scaling Correction Factor; LL = LogLikelihood; BIC = Bayesian Information Criterion; SABIC = Sample-size Adjusted BIC; AIC = Akaike's Information Criterion; CAIC = Consistent AIC; LMRA = p-value of the Lo-Mendell-Rubin Adjusted Likelihood Ratio Test; BLRT = p-value of the Bootstrapped Likelihood Ratio Test; SGP = Smallest Group Proportion based on estimated model; NG < 8% = Number of Groups with a proportion below 8%; LCP = Lowest Classification Probability; * = p-value < .05

[a] Final profile

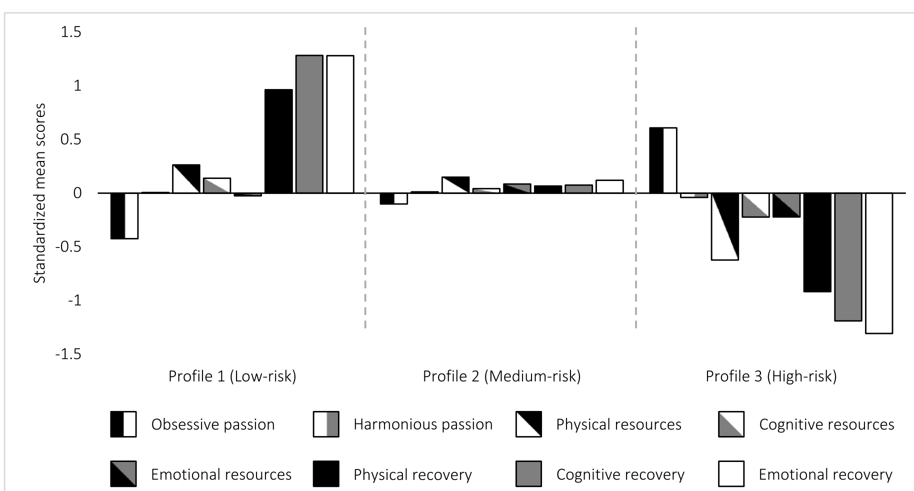

Fig. 1. Visual representation of the 3-profile solution based on psychological indicators.

($\chi^2(df = 2) = 7.753$, $p = .021$). The high-risk profile scored 23.5 percentage points higher on RRI incidence compared to the low-risk profile, which proved significant ($LLCI = 6.1$, $ULCI = 40.8$; $\chi^2(df = 1) = 7.153$, $p = .007$, $d = 0.429$). In line with expectations though not significant, the high-risk profile scored 11.4 percentage points higher than the medium-risk profile ($LLCI = -0.8$, $ULCI = 23.7$; $\chi^2(df = 1) = 3.346$, $p = .067$, $d = 0.228$) and the medium-risk profile scored 12.1 percentage points higher than the low-risk profile ($LLCI = -28.8$, $ULCI = 4.7$; $\chi^2(df = 1) = 1.990$, $p = .158$, $d = 0.155$).

7.2.3. *Relation with chronic fatigue*

Standardized chronic fatigue scores differed across profiles; we found that the low-risk profile had the lowest fatigue score ($M = -0.501$, $SE = 0.144$) whereas the medium-risk ($M = 0.101$, $SE = 0.064$) and high-risk profile ($M = 0.093$, $SE = 0.121$) both scored higher. The overall test for differences was significant ($\chi^2(df = 2) = 13.958$, $p = .001$). The low-risk profile scored a significant 0.60 *SD* lower on chronic fatigue than the medium-risk profile ($LLCI = -0.93$, $ULCI = -0.28$; $\chi^2(df = 1) = 13.009$, $p = <.001$, $d = 0.404$) and a significant 0.59 *SD* lower than high-risk profile ($LLCI = -0.96$, $ULCI = -0.23$; $\chi^2(df = 1) = 10.049$, $p = .002$,

Table 3
Estimates on indicators and outcomes of the 3-profile solution.

Indicators (UE)	Low-risk profile (16.5%[a])		Medium-risk profile (61.7%[a])		High-risk profile (21.8%[a])	
	Z (*SE*)	*p*-value	*Z* (*SE*)	*p*-value	*Z* (*SE*)	*p*-value
Obsessive passion (.22)	−0.42 (0.12)	≤.001 *	−0.10 (0.06)	≤.079	0.61 (0.17)	≤.001 *
Harmonious passion (.16)	0.01 (0.18)	≤.972	0.01 (0.07)	≤.855	−0.04 (0.12)	≤.733
Physical resources (.22)	0.26 (0.16)	≤.097	0.15 (0.06)	≤.020 *	−0.62 (0.16)	≤.001 *
Cognitive resources (.16)	0.14 (0.18)	≤.429	0.04 (0.07)	≤.565	−0.22 (0.13)	≤.079
Emotional resources (.16)	−0.03 (0.17)	≤.884	0.09 (0.07)	≤.219	−0.22 (0.12)	≤.070
Physical recovery (.35)	0.96 (0.12)	≤.001 *	0.07 (0.08)	≤.423	−0.92 (0.13)	≤.001 *
Cognitive recovery (.55)	1.28 (0.16)	≤.001 *	0.08 (0.08)	≤.318	−1.19 (0.14)	≤.001 *
Emotional recovery (.62)	1.28 (0.14)	≤.001 *	0.12 (0.08)	≤.138	−1.31 (0.12)	≤.001 *
Outcomes	**Probability/*Z* (*SE*)**		**Probability/*Z* (*SE*)**		**Probability/*Z* (*SE*)**	
RRI probability	47.4%	(7.2%)	59.1%	(3.3%)	70.7%	(5.1%)
Chronic fatigue	−0.50	(.14)	0.10	(.06)	0.09	(.12)

Note: UE = Univariate Entropy, the degree to which an indicator is informative in identifying the latent profile; RRI = Running-related injury; $^*p < .05$
[a] The final profile proportion of the total sample (N = 425) based on the estimated model, as an indication of prevalence.

$d = 0.513$). The difference between the high risk and medium risk profile at −0.01 *SD* was not significant (*LLCI* = −0.26, *ULCI* = 0.24; $\chi^2(df = 1) = 0.004$, $p = .951$, $d = 0.007$).

8. Discussion

Using a functional self-regulation perspective, the present cross-sectional survey study investigated the association between (1) psychological factors of recreational long-distance runners and (2) their running-related injuries (RRIs) and chronic fatigue. By means of a non-confirmatory and person-centered approach, we empirically identified three distinct psychological risk profiles of long-distance runners based on running-related resources, running-related recovery, and passion for running. These psychological risk profiles were associated with RRIs and chronic fatigue, and were termed the low-risk, medium-risk, and high-risk profile accordingly. The low-risk profile was characterized by low obsessive passion for running and high physical, cognitive, and emotional recovery from running. The medium-risk profile showed average scores on both types of passion, resources, and recovery, not deviating strongly on any variable. The high-risk profile, in line with our propositions, featured high obsessive passion, low physical, cognitive, and emotional recovery, as well as low physical resources. In terms of associations with RRIs and chronic fatigue, the low-risk profile showed a significantly lower injury incidence than the high-risk profile. The low-risk profile also exhibited significantly lower chronic fatigue than both the medium-risk and the high-risk profile. Contrary to expectations, harmonious passion and, to a lesser degree, running-related resources did not play a substantial role in differentiating these profiles.

8.1. Implications for the understanding of running-related injuries and chronic fatigue

Several important implications of this study can be drawn. The first set of implications concern the contribution of the psychological risk profiles in their association with running-related health outcomes. First, and most importantly, our findings establish that the three psychological risk profiles are associated with RRIs and chronic fatigue in long-distance runners. On account of their proposed namesake, we find that the low-risk profile is associated with fewer RRIs and chronic fatigue than the medium-risk and high-risk profiles. Specifically, the low-risk profile scored 47%, the medium-risk 59%, and the high-risk profile reached a 71% injury probability. Although no difference with the medium-risk profile was found ($p = .067$), the low-risk profile injury probability was significantly lower than the high-risk profile. With regards to chronic fatigue, the low-risk profile showed a chronic fatigue score significantly lower than the medium-risk and high-risk profile. These risk profiles and their respective associations with RRIs and chronic fatigue highlight the importance of considering psychological factors in understanding the incidence of RRIs and chronic fatigue in runners.

Second, the congruence of RRIs and chronic fatigue across risk profiles indicates the potential of a shared risk factor across both outcomes. This aligns with other studies, as general fatigue has been proposed to increase the injury risk through a combination of psychological and biomechanical factors (Bittencourt et al., 2016), particularly among less-trained runners (Tam et al., 2017). The psychological uncontrolled nature of a high-risk profile likely predisposes such runners to RRIs and chronic fatigue through implied behaviors responsible for overuse injuries (e.g., Martin et al., 2021). The low-risk profile, in contrast, portrays a more controlled approach where runners are more capable of recovering from their sport. Altogether, our inclusion of both outcomes gives a more complete perspective on long-distance running. It helps unveil how psychological profiles may function as a simultaneous common risk factor for both RRIs and chronic fatigue, also illustrating that a better understanding of chronic fatigue might aid the understanding of RRIs.

The importance of these findings is underlined by the high incidence scores of RRIs we encountered. Nearly 60% of our sample reported having developed an RRI over the past 12 months, which is consistent with similarly oriented studies (e.g., 58%, van Poppel et al., 2018; see also van Poppel et al., 2020). This injury rate reaffirms previous findings showing that people who practice running have a notably higher risk of getting injured than those who, for example, practice tennis, fitness, or martial arts, with only field soccer players having a higher risk (see Stam & Valkenberg, 2019). This signals a larger problem with injuries in long-distance running as compared with other sports. Concerning chronic fatigue, the overall score (i.e., 2.1 ± 0.5) indicates that our sample of long-distance runners scored significantly higher than a more general population (i.e., 1.9 ± 0.6; Michielsen et al., 2004), although the associated effect size was relatively small. Whilst clinical relevance could not be established on account of the absence of a meaningful cut-off point for this measure in a sport-related context, the relative differences still illustrate the safety of the low-risk profile. In adding nuance to these findings, we note that most of the established effect sizes were categorizable as small (see Lenhard & Lenhard, 2016). This signals that, although psychological profiles do play a substantial role, indicators in risk profiles need to be finetuned to strengthen their predictive ability in prospective designs, thereby improving our understanding of their mechanisms. Finally, despite being an incipient topic in long-distance running, the congruence of RRIs and chronic fatigue across profiles suggests that complementing assessments of RRIs with chronic fatigue measures in future research may prove beneficial to prevent dropout from running.

8.2. Theoretical implications of psychological risk profiles

Adopting a person-centered approach, our study offers several theoretical contributions as well. The psychological ingredients (i.e., passion, resources, and recovery) for the three profiles distinguished using LPA were based on a self-regulation perspective, resulting in several combinations befitting this line of thinking. In these risk profiles, we considered running-related resources and recovery to be indicators of functional self-regulatory behavior (de Jonge et al., 2020; McCormick et al., 2018), and the two types of passion for running to relate to the functionality of self-regulation by their association with those resources and recovery (Stenseng et al., 2011; Stenseng et al., 2015). The risk profiles that were found reinforce the proposition that obsessive passion for running is associated with lower usage of self-regulatory running-related strategies (i.e., recovery and, to a lesser degree, resources). These findings are in line with other studies (e.g., de Jonge et al., 2020; Stenseng et al., 2011) that link obsessive passion with deficiencies in self-regulation, indicating a certain loss of control that likely causes runners to directly or indirectly tax their bodies beyond their limits. Thereby the current study supports the theoretical stance of a deficiency in self-regulation being associated with RRIs and chronic fatigue.

In explaining these relations, Verner-Filion et al. (2014) have proposed that athletes with an obsessive passion for their sport may avoid dealing directly with stressors due to the importance of this activity in their identity. In their study, obsessive passion led to more anxiety through such avoidance-oriented coping strategies. The authors also mentioned that obsessively passionate athletes might be prone to 'not letting go' and ruminating about negative sport-related experiences. Aligning with these statements, we find that above-average obsessive passion coincides with below-average recovery scores in our sample. Although the same pattern need not always surface (e.g., de Jonge et al., 2020), combining 'occasionally letting go' while also 'fully integrating' an activity seems challenging for those high in obsessive passion. This difficulty was also highlighted in a study among nurses, which showed obsessive passion to preclude detachment as a recovery experience (Donahue et al., 2012). Their explanation of rigid engagement in work as induced by obsessive passion preventing work-related recovery likely applies to the running context in a very similar fashion. Obsessive passion for running has also been suggested to play a role in injury development in runners by directly affecting training-related factors (Mousavi, 2020), perhaps indicating failure in self-regulation. Given the overlap of obsessive passion with exercise addiction (e.g., Nogueira et al., 2018), and relation with 'escapism' (Stenseng et al., 2011), which is itself related to lower levels of self-control and maladaptive emotion regulation, obsessive passion is thus likely to coincide with lower levels of recovery and, incidentally, employment resources. Thereby, our findings align with those of prior research to suggest that obsessive passion disrupts the application of self-regulatory efforts and that this pattern may be associated with RRIs and chronic fatigue.

Contrary to expectations, harmonious passion and running-related resources did not contribute to the risk profiles in a meaningful or consistent pattern, as indicated by their low univariate entropy as well (see Table 3; Asparouhov & Muthén, 2018). Although the combinations of variables shape the main content of this manuscript, it is also important to discuss these individual variables considering the lack of comparable profile-based research. Concerning harmonious passion, we expected higher scores to coincide with higher use of self-regulation strategies, but no meaningfully deviating score of harmonious passion was found in the three psychological risk profiles of long-distance runners. Although other literature has supported the link of harmonious passion with more adaptive behaviors (e.g., Curran et al., 2015), perhaps such variation was already captured by other variables within the current framework, or it may have been otherwise obscured by our methodology. A recent quadripartite approach to passion also highlighted the positive role of harmonious passion for health by using predetermined combinations of both types of passion (Schellenberg et al., 2018), in contrast with the naturally generated risk profiles we found in this study. Although this methodological aspect is one among many differences (e.g., target sample, theoretical approach, positive versus negative outcomes), it could be worthwhile to compare both approaches in future studies. Running-related resources also lacked consistent distinguishing patterns across profiles. We found negative associations between obsessive passion and physical and cognitive resources, but these did not translate into distinctive aspects of risk profiles. Perhaps this indicates that runners are capable of employing resources regardless of their obsessive passion. However, this would conflict with our propositions, as many of these resources concern a certain amount of control and influence over one's sport (e.g., van Iperen et al., 2020), something we would expect to relate to obsessive passion for sport, as they are indicators of self-regulation. Given the role of sport-related resources in other self-regulatory research in athletes (e.g., Balk, 2018), it would be interesting to see whether future studies will find similar outcomes in relation to passion for sport.

In all, the low-risk and high-risk profiles seem to indicate a predisposition towards more and less functional self-regulatory patterns, respectively. As our approach is relatively novel and specific, there are, unfortunately, no LPA studies to which we can compare these psychological risk profiles. Although other studies have shown negative associations between obsessive passion for sport and mental detachment from sport (e.g., de Jonge et al., 2020; Donahue et al., 2012), there are no studies explicitly testing our LPA setup with passion, resources, and recovery. To conclude, our findings suggest further research to verify self-regulatory mechanisms in the prediction and prevention of RRIs and chronic fatigue.

8.3. Strengths, limitations, and suggested future directions

A strength of our study entails the use of a person-centered approach. By using LPA, we were able to link running-related outcomes to a limited number of evidence-based, meaningful psychological risk profiles. Our generated profiles show a clearly differentiated and heterogeneous interplay of indicators and outcomes. Although the approach is relatively novel - which limits current comparability - we believe it is an important step forward in a better understanding of RRIs and chronic fatigue (see Ivarsson & Stenling, 2019; Martin et al., 2021). Our approach is arguably another strength of this study, as we align with the complex systems paradigm in approaching sports injuries, as proposed by Bittencourt et al. (2016), to better understand injury incidence. A final strong suit of our research lies in the adequately sized and representative sample, further empowering generalizability to recreational long-distance runners in general.

In terms of limitations, we first note that the selection of the exact number of psychological risk profiles is not completely free of subjective judgment and interpretation. Further research into the validity and reproducibility of the current profiles is therefore recommended. Second, we could not control for external training loads, such as weekly running hours or frequency, opening up an interesting avenue for future studies to determine how training behaviors fit with our current findings (e.g., Lopes & Vallerand, 2020). A third limitation is the use of cross-sectional self-report data, which limits the study's internal and external validity and precludes judgment on temporal order and causality. Furthermore, given the retrospective question pertaining to RRIs, we can only imply an association between (1) the three psychological risk profiles and (2) injury incidence and chronic fatigue scores. It is also possible the RRIs led to profile membership, or that they simply co-occurred based on some confounding variable(s). The presumption of temporal stability of the distinguished profiles could strengthen the conclusions of this paper, yet in the absence of such data or studies we can only report the current association. A fourth limitation concerns potential confounders that may be associated with both profile membership and outcomes. Although outside the current scope as an in-depth topic, we conducted post hoc tests for potential confounders such as body mass index, gender, education level, and age. Of these variables, we found only age to be significantly related to profile membership (i.e., showing a negative association with risk). The general absence of significant confounders strengthens the role of psychological risk profiles. Yet, the relation with age remains interesting, although the age-RRIs relation is rather ambivalent in the academic literature (e.g., van Poppel et al., 2020). It is likely that less injured runners more often 'survive' in running, explaining the role of age in our study (i.e., "healthy runner effect"; Warne et al., 2021). For now, the role of age can be a topic for future studies, also given the rather narrow age range (i.e., between 40 and 50 years old) in the current study. A fifth limitation involves the external validity of our study. Given that our analyses concern one sample from one sport in a single country, it would be interesting whether the current findings can be replicated in diverging contexts. We emphasize that we study tendencies in complex interactions, which is why we do not necessarily expect exact replications of our findings but rather the replication of tendencies befitting our theoretical perspective. Sixth, we asked participants to self-report injuries over the past 12 months, which may invoke some level of recall bias. Yet, multiple studies (e.g., Smits et al., 2018) have shown that validity in injury recall is generally unimpeded when focusing on general aspects of the injury (e.g., present or not present) as opposed to specific aspects (e.g., type). A final limitation also lies in our measurement of injuries, as we did not differentiate various origins of injuries (e.g., acute, overuse), whereas certain self-regulatory patterns may be linked more to overuse injuries (e.g., van der Sluis et al., 2019).

For future research, we recommend that scholars consider other sports (e.g., similar endurance sports such as cycling or ice-skating) and even other cultures in replicating the findings of the current study. It is likely that common risk profiles exist with specific nuances per sport and per culture. In doing so, self-regulatory ability, as indicated in this study by adequate employment of coping strategies, may also be approached from different angles. In line with the review by McCormick et al. (2018) on the topic of self-regulation in endurance sports, we suggest the implementation of the cyclical nature of self-regulation, as well as specific metacognitive skills commonly thought to be employed in that process (e.g., planning, monitoring, reviewing). Additionally, it would be valuable to observe more multidisciplinary and complete combinations (i.e., including mental, physical, behavioral, and social indicators in unison) to enhance predictive accuracy (e.g., Besomi et al., 2018). A relatively simple illustration could be to determine the exact interplay between psychological risk profiles and training behaviors. Future research could also focus on targeted prevention and management practices, involving psychological risk profiles in order to reduce negative outcomes of running, as highlighted in the current person-centered approach (see also Selfe et al., 2016). Pinpointing optimal thresholds for assigning runners to certain profiles and optimizing the use of subjective psychosocial measures in assessing athlete well-being (see Saw et al., 2015) may prove a worthwhile new avenue. Equally important would be to study RRIs and chronic fatigue in unison. With regards to RRIs, new measures may further improve validity of such studies (e.g., Clarsen et al., 2020). Furthermore, prior research has highlighted the importance of differentiating injury types in terms of mechanism and onset, such as acute and overuse injuries (Bahr et al., 2020), which would serve as a strong improvement upon the current study (see also Vallerand, 2010; van Poppel et al., 2020). Finally, we recommend using longitudinal and confirmatory LPA research in follow-up studies (e.g., Besomi et al., 2018; Martin et al., 2021). This could improve upon our current approach in two ways. First, by allowing one to determine the stability and change of risk profiles over time both within and between persons. Second, to establish whether risk profiles are predictive of future injury, fatigue scores, intervention efficacy, and other outcomes in prospective designs across contexts and cultures.

8.4. Practical recommendations

Psychological risk profiles may help identify vulnerable runners and thereby prove useful for targeted early prevention practices (e.g., Selfe et al., 2016). Our risk profiles exhibit strong differences in their potential to enable long-term sustainable running. This is illustrated by the possibly preventative effect of low-risk profile characteristics (i.e., low obsessive passion and high recovery) as well as by the potentially detrimental effect of the high-risk group characteristics (i.e., high obsessive passion and low recovery). The cross-sectional nature of our study limits strong recommendations for real practice. We will nevertheless suggest a few practical implications. A first step for recreational long-distance runners may lie in determining their own psychological risk profile. Do they feel like they cannot control their urge to run? Do they feel like they are rarely recovered from their sport? Those with high-risk profiles may attempt to improve their functional self-regulation of these aspects, which may prove more useful for recovery from running than for obsessive passion, given the relatively stable nature of the latter (Berg et al., 2020). Still, reducing obsessive passion by reappraising the importance of running and the associated efforts, such as by engaging in an interesting non-running activity (Vallerand & Verner-Filion, 2020), may aid in reducing the loss of control. Above all, the general aim should be to reduce the inability of runners to functionally self-regulate their running-related efforts. Many recreational long-distance runners strive for improvement and achievements yet losing yourself in running may be suboptimal for health-related reasons. Occasionally letting go, purposefully missing your chance to blow, and realizing that opportunities come more than once in a lifetime may yield a more healthy and sustainable approach to long-distance running. In terms of recovery from running, runners should also be aware that not being mentally or physically engaged in running is also important in sustainably training. Runners should consider their mental detachment and recovery activities, and should try to truly 'disconnect' from their sport during their 'off' moments. For this purpose, we recommend the article by Eccles et al. (2021), which provides practical recommendations to promote mental rest in athletes. Running coaches can consider an initial, structured screening for high-risk runners and can try to intervene as early as possible, such as by applying the suggestions given above. Running coaches may also play a role in safely dosing running (i.e., 'being their handbrake'). For example, the ability to choose and adapt running training sessions to individual needs serves runners with high levels of freedom. Yet, this heterogeneity of training choices seems a double-edged sword for recreational runners (Warne et al., 2021), as it may also overwhelm and inhibit adequate self-regulation, which running coaches may help prevent. In all, given the common risk factor for both RRIs and chronic fatigue, running coaches and runners alike may hit the proverbial 'two birds with one stone' by pre-emptively modulating high-risk profile characteristics.

9. Conclusion

This study aimed to explore psychological factors and risk profiles associated with running-related injuries and chronic fatigue among recreational long-distance runners. To this end, we adopted a person-centered approach by which we identified three psychological risk profiles. We found that these three distinct risk profiles were associated with running-related injury incidence and chronic fatigue, largely in line with our propositions on passion for running and functional self-regulation. Our results thereby highlight the importance of specific combinations of obsessive passion for running and running-related recovery in their association with RRIs and chronic fatigue. In sum, and in alignment with a complex systems approach to injury prevention, this study thus enables differentiating risk categories in long-distance runners based on their psychological risk profiles.

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CRediT authorship contribution statement

Luuk P. van Iperen: Conceptualization, lead, Data curation, Methodology, Formal analysis, Investigation, lead, Writing – original draft, Writing – review & editing, equal, Project administration, Visualization. **Jan de Jonge:** Conceptualization, lead, Investigation, supporting, Writing – review & editing, equal, Supervision, equal, Project administration, Funding acquisition. **Josette M.P. Gevers:** Conceptualization, supporting, Writing – review & editing, equal, Supervision, equal. **Steven B. Vos:** Conceptualization, supporting, Investigation, supporting, Writing – review & editing, supporting.

Declaration of competing interest

We have no conflicts of interest to disclose.

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