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ORIGINAL RESEARCH

Can we explain running-related injury preventive behavior? A path analysis

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Abstract
Background: Behavioral and social science theories/models have been gaining attention in sports injury prevention.
Objective: To investigate the potential of the Theory of Planned Behavior in explaining running-related injury preventive behavior.
Methods: Six-month prospective cohort study based on data gathered from a randomized controlled trial. From a total of 1512 invited trail runners, 232 were included in this study. Preventive behaviors and their determinants were assessed at baseline and two and six months after baseline. Five-point Likert scales were used to assess the determinants of preventive behavior. A Bayesian path analysis was conducted applying mixed models and mediation analysis.
Results: A 1-point increase in intention, attitude, subjective norm, and perceived behavioral control predicted an increase of 54% (95% Bayesian credible interval [BCI]: 38, 71) in the rate of performing running-related injury preventive behavior, explaining 49% (R^2 0.49; 95% BCI: 0.41, 0.56) of the variance around preventive behavior. Intention and perceived behavioral control predicted running-related injury preventive behavior directly, while 40% (95% BCI: 21, 61) and 44% (95% BCI: 20, 69) of the total effect of attitude was mediated by intention and perceived

Trial registration: NTR5431 (https://www.trialregister.nl/trial/5322)

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behavioral control, respectively. Attitude, subjective norm, and perceived behavioral control predicted intention.
Conclusions: The Theory of Planned Behavior may have the potential to explain half of the variance around running-related injury preventive behavior and intention. Therefore, such theory may be considered a relevant and useful tool in developing, investigating, and/or implementing programs aimed at preventing running-related injuries.
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Introduction

Behavioral and social science theories and conceptual models have been gaining attention in the field of sports injury prevention.[1-4] The importance of understanding and considering behavioral approaches in sports injury prevention lies in the evidence suggesting that implementing prevention or rehabilitation programs in real-world settings rely extensively upon the implementation context that is composed of behaviors and their determinants in different levels: individual; societal (e.g. groups and providers); organizational (e. g. clinics, clubs and hospitals); and structural (e.g. health systems).[3,5] Therefore, knowing how to influence and change behaviors related to an individual's environment is key for physical therapists to achieve the desired adherence and effectiveness of a proposed intervention program.[6,7]

Systematic reviews[2,8] summarized the evidence on the use of behavioral and social science theories and conceptual models in sports injury prevention and concluded that: (1) although there has been an increase in the use of such theories/models over time, there has been still few studies explicitly using these theories/models; and that (2) the Theory of Planned Behavior[9-11] was one of the most used.[2] Briefly, the Theory of Planned Behavior postulates that a given behavior can be predicted by intention and perceived behavioral control towards such behavior.[9-11] In turn, intention is determined by attitude, subjective norm, and perceived behavioral control. Intention captures the motivational factors that influence behavior. Attitude is the result of the beliefs about the consequences of the behavior. Subjective norm refers to the beliefs on what others think about the person performing the behavior. Perceived behavioral control is the results of the perceived ease or difficulty in performing the actual behavior. These characteristics are known as 'determinants of behavior.'[9-11]

The determinants of behavior have been investigated for some injury preventive behaviors in sports like skiing,[12] skating,[13] Australian football,[14] basketball,[15] netball,[16] soccer,[17] running[18] and in female high school athletes[19] (field hockey, soccer, and volleyball). However, there is a paucity of scientific evidence on the potential of behavioral and social science theories in explaining sports injury preventive behaviors. Understanding the determinants influencing behaviors is important to facilitate behavior changes that are required to improve adoption and adherence of prevention programs.[2,8] In turn, a higher 'uptake' of sports injury prevention programs may enhance the effectiveness of such interventions.[7,20,21]

A pioneering study[18] using the Theory of Planned Behavior in the development of a running-related injury prevention program presented a risk reduction of 13% (95% Bayesian credible interval [BCI]: −23.3, −3.1) between the intervention group (program based on tailored advice delivered every two weeks) and the comparison group (general advice delivered only once in the beginning of the study) in six months of program implementation. However, the intervention was not effective in changing running-related injury preventive behavior and its determinants.[18] These results raised the following research question: what is the potential of the Theory of Planned Behavior model in explaining running-related injury preventive behavior? Hence, investigating this research question was the purpose of this study. To achieve such purpose, the research question was translated into four specific objectives: (1) to investigate the association between intention and running-related injury preventive behavior; (2) to investigate the association of attitude, subjective norm, and perceived behavioral control with intention toward running-related injury prevention; (3) to investigate the association among attitude, subjective norm, and perceived behavioral control; and (4) to investigate the mediators of the effects between the determinants of behavior and running-related injury preventive behavior.

Methods

Study design

This is a secondary analysis of a randomized controlled trial.[18] The protocol of the randomized controlled trial has been prospectively registered in the Netherlands Trial Register (NTR5431). For this secondary analysis the data were treated as a 6-month prospective cohort, since there were no differences between intervention groups regarding preventive behavior and its determinants.

Participants

A total of 1512 runners from the *MudSweatTrails* database registered to participate in trail running events in the Netherlands was invited to partake in the study. Trail runners who agreed to participate through online informed consent and aged 18 years or over were eligible for the study. The medical ethics committee of the VU University Medical Center Amsterdam had approved the study (2015.302). Informed consent was obtained from all individual participants included in the study through an online informed consent form that was previously revised and approved by the VU University Medical Center Amsterdam medical ethics committee.

Data collection

The data were collected between November 2015 and May 2016. Invitations and all data collection were conducted online. Individuals from the target population received an e-mail briefly explaining the purpose and the procedures of the study. Trail runners interested in participating were invited to access the online informed consent form with more information about the study through a link in the invitation email. Those who agreed to participate were then invited to access the baseline questionnaire aimed at gathering the following information: age, sex, body height, body mass, educational level, running (total and trail) experience, previous running-related injuries (last 12 months), and running-related injury at baseline. A running-related injury questionnaire was applied every two weeks using the Dutch online version of the Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems.[18,22,23] The definition of running-related injury used in this study was 'any disorder of the musculoskeletal or integumentary systems, or concussions experienced or sustained by an individual during participation in running.'[18,24] After fulfilling the baseline questionnaire, the participants were referred to a preventive behavior questionnaire. Preventive behavior towards running-related injury and its determinants were assessed at three time-points: baseline and two and six months after baseline. The preventive behavior questionnaire in full can be found in the supplementary material of the trial.[18] For all questionnaires, if no response was received within a week, a reminder was sent by email, encouraging the participant to complete the questionnaire.

Preventive behavior questionnaire

Preventive behavior was assessed by a multiple-choice question, where participants could choose as many options as they wished from a list composed of 15 prespecified running-related injury preventive behaviors and an 'other' option (a free text field), where they could register any preventive behavior not prespecified. The advice to prevent running-related injuries in trail runners delivered every two weeks during the study (*TrailS$_6$*)[18] aimed to facilitate the implementation of seven of the 15 preventive behaviors assessed. Therefore, the questions about the determinants of preventive behavior assessed the determinants of implementing the following seven *TrailS$_6$* preventive behaviors as an advice package: (1) performing warming-up exercises; (2) performing cooling-down exercises; (3) using specific trail running shoes; (4) performing strength training; (5) performing core training; (6) performing neuromuscular (balance and/or proprioception) training; and (7) performing flexibility training. Preventive behavior was, therefore, treated as a 0−7-count variable in this study, where the more behaviors a trail runner implemented, the higher the preventive behavioral level.

Determinants of preventive behavior

Five-point Likert scales (−2 to 2) were used to score the determinants of preventive behavior.[25,26] Higher scores indicated higher determinant levels. A single question assessed intention: '*Do you intend to follow the advice suggested by this study to prevent running injuries?*'. Answers could range from 'no, certainly not' (−2) to 'yes, certainly' (2). Attitude was assessed by the good-bad and the pleasant-unpleasant rating of the same statement ('*I find following advice on running injury prevention...*'), and by one question ('*Do you believe it is possible to prevent running injuries?*') with answer options ranging from 'no, definitely impossible' (−2) to 'yes, definitely possible' (2). The average of the three attitude items was used in the analysis.[26] Subjective norm was assessed by the 'no, definitely not' (−2) to 'yes, definitely' (2) rating of the following single statement: '*People from my social circle believe I should follow advice on running injury prevention*'. Perceived behavioral control was assessed by the able-unable and the easy-difficult rating of the same following statement: '*If I want to follow advice on running injury prevention, I am / this will be...*'. The average of the two perceived behavioral control items was used in the analysis.[25,26] All variables regarding the determinants of behavior were treated as continuous variables in this study.

Data analysis

Descriptive analyses were performed to summarize the baseline and follow-up characteristics of the participants. Continuous data presenting a normal distribution were described as mean and standard deviation (mean ± SD), or the 95% frequentist confidence interval (95% CI).[27] Numeric variables presenting a non-normal distribution were described as median and 25% to 75% interquartile range (median [IQR]). Dichotomous and categorical data were presented as frequency (n) and percentage.

The path analyses were conducted following the Bayesian approach to account for the a priori hypotheses on the Theory of Planned Behavior. Because the structure of the dataset was longitudinal, mixed models were implemented to account for the dependency and changes in the repeated measurements. Therefore, all models were fit including an indication variable for the repeated measurements for each participant as an intercept random effect. The informative priors were used based on previous evidence on the Theory of Planned Behavior paths.[9,13,28-32] A Bayesian version of the R^2 was estimated to provide evidence related to the explained variance around the dependent variable for each model.[33] Mediation analyses were conducted to estimate natural direct effects, natural indirect effects, total effects, and the proportion mediated.[34,35]

Poisson mixed models (1 to 3) were implemented when including preventive behavior as the dependent variable. Model 1 was fit with the purpose of investigating the unadjusted association between intention and preventive behavior. Therefore, only intention was included as the independent variable in the fixed effect part of this model. The purpose of models 2 and 3 was to investigate the association of the determinants of behavior with preventive behavior, adjusted for the remaining determinants. Therefore, all determinants were included as independent variables in the fixed effect part of these models.

Linear mixed models (4 to 7) were implemented when including one of the determinants of behavior as the dependent variable. All linear models were fit with the purpose of investigating the association among the determinants according to the Theory of Planned Behavior hierarchy (Fig. 1). Therefore, each model included the remaining

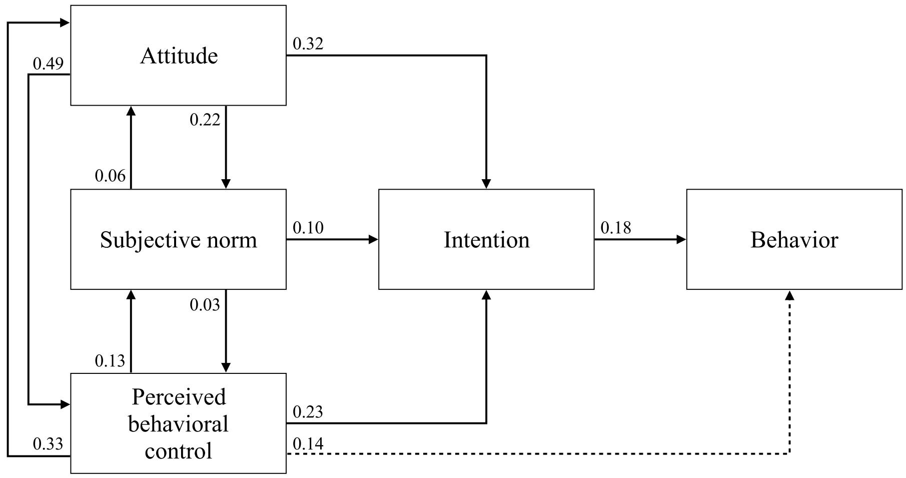

Fig. 1 The Theory of Planned Behavior with the regression coefficients (β) showing the relationship between preventive behavior toward running-related injury and its determinants.

determinants as independent variables in the fixed effect part of the models.

All analyses were performed in R 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria). Bayesian analyses were conducted using the 'brms' package.[36] The results were summarized based on sampling from the posterior distributions using the No-U-Turn sampler[37] with five chains, 20 000 iterations, and disregarding the initial 5000 iteration of each chain.[18] Summary statistics included regression coefficients (β), rate ratios (RR), and the 95% BCI.[27]

Results

Characteristics of the cohort

The sample was composed of 232 trail runners, 157 (68%) men and 75 (32%) women. Table 1 presents the personal, running, and injury characteristics at baseline. Ten participants dropped out of the study during the 6-month follow-up period, however, their available data were included in the analysis until the time they dropped out. The response rate was 81% [72, 91], on average. From the 173 trail runners free of running-related injuries at baseline, 124 reported 194 new running-related injuries in a total of 12 125 h of running. This led to a cumulative incidence proportion of 72% (n = 124/173) and an incidence density of 16 running-related injuries per 1000 h of running (95% CI: 14, 18). Table 2 summarizes the reported preventive behaviors toward running-related injury and their determinants over time. The preventive behaviors most performed, regardless of the time point in the study, were: using specialized trail running shoes, performing core training, performing warming up, and performing strength training.

Table 1 Personal, running, and injury characteristics of the trail runners at baseline.

Characteristics	All n = 232	Free of running-related injury at baseline n = 173	Running-related injury at baseline n = 59
Sex			
Man	157 (68%)	119 (69%)	38 (64%)
Woman	75 (32%)	54 (31%)	21 (36%)
Age (years)	44.6 ± 9.5	44.6 ± 9.8	44.5 ± 8.7
Height (cm)	178.2 ± 8.6	177.8 ± 8.4	179.2 ± 9.3
Body mass (kg)	72.7 ± 11.3	72.3 ± 11.1	73.6 ± 11.9
BMI (kg/m^2)	22.8 ± 2.3	22.8 ± 2.4	22.8 ± 2.1
Educational level			
Primary	5 (2%)	5 (3%)	–
Secondary	159 (69%)	122 (71%)	37 (63%)
Tertiary	68 (29%)	46 (27%)	22 (37%)
Running experience (years)	9 [5, 20]	8 [5, 20]	10 [4, 20]
Trail running experience (years)	3 [2, 4]	3 [2, 4]	3 [2, 4]
Previous running-related injury (12 months)	96 (41%)	65 (38%)	31 (53%)

Data are mean ± SD, median [25th, 75th percentiles IQR], or frequency (proportion).
BMI, body mass index; IQR: interquartile range; SD, standard deviation.

Table 2 Description of running-related injury preventive behaviors and their determinants.

Variable	Baseline *n* = 232	2-month follow-up *n* = 189	6-month follow-up *n* = 143
Preventive behaviors			
Trail running shoes	137 (59%)	86 (46%)	65 (45%)
Core training	127 (55%)	106 (56%)	76 (53%)
Warming up	122 (53%)	87 (46%)	73 (51%)
Strength training	108 (47%)	80 (42%)	65 (45%)
Cooling down	95 (41%)	77 (41%)	55 (38%)
Flexibility training	93 (40%)	62 (33%)	53 (37%)
Neuromuscular (balance and/or proprioception) training	68 (29%)	45 (24%)	34 (24%)
Determinants*			
Intention	1.2 (1.1, 1.3)	1.2 (1.1, 1.4)	1.2 (1.0, 1.3)
Perceived behavioral control	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)
Attitude	1.2 (1.1, 1.3)	1.2 (1.2, 1.3)	1.3 (1.2, 1.4)
Subjective norm	0.5 (0.3, 0.6)	0.6 (0.4, 0.7)	0.7 (0.5, 0.9)

Data are frequency (proportion) or mean (95% frequentist confidence interval [CI]).
* The determinants of running-related injury preventive behaviors were measured by 5-point Likert scales ranging from −2 to 2.

Path analysis

The first objective was to determine the association between intention and running-related injury preventive behavior. Table 3 and Fig. 1 present the results of the Bayesian mixed models. Intention was associated with running-related injury preventive behavior (models 1, 2, and 3). Intention alone explained 48% (R^2 0.48; 95% BCI: 0.40, 0.55) of the variance around preventive behavior (model 1). Adding perceived behavioral control, attitude, and subjective norm (models 2 and 3) to the model did not change the magnitude of the explained variance. However, perceived behavioral control was associated with preventive behavior when adjusted for intention, attitude and subjective norm (models 2 and 3). Subjective norm was not associated with running-related injury preventive behavior; for that reason, subjective norm was not included in the mediation analysis (Table 4).

A 1-point increase in all determinants (i.e. toward higher intention, attitude, subjective norm, and perceived behavioral control in 5-point Likert scales) was associated with an increase of 54% (95% BCI: 38, 71) in the likelihood of performing running-related injury preventive behavior. This model (Table 3; model 3) explained 49% (R^2 0.49; 95% BCI: 0.41, 0.56) of the variance around running-related injury preventive behavior.

The second and third objectives were to determine the association between the distal determinants and intention, and among the distal determinants. Attitude, subjective norm, and perceived behavioral control were all associated with intention (Table 3; model 4). This model explained 50% (R^2 0.50; 95% BCI: 0.43, 0.56) of the variance around intention. A 1-point increase in all distal determinants (i.e. toward higher attitude, subjective norm, and perceived behavioral control in 5-point Likert scales) was associated with an increase of 0.66 point (95% BCI: 0.55, 0.75) in intention (5-point Likert scale) toward running-related injury preventive behavior. The associations among the distal determinants of behavior can be found in models 5, 6, and 7 described in Table 3.

The fourth objective was the mediation analysis. Table 4 presents the results of the mediation analysis. Forty percent (95% BCI: 21, 61) and 25% (95% BCI: 10, 43) of the total effects of attitude and perceived behavioral control on preventive behavior was mediated by intention, respectively. A small proportion of the total effect of intention was mediated by perceived behavioral control (9%; 95% BCI: 1, 18) or attitude (12%; 95% BCI: 4, 21) as a result of small indirect effects (Table 4). Therefore, intention was confirmed as the central determinant of running-related injury preventive behavior, mediating the effects of attitude, and perceived behavioral control on preventive behavior.

The proportion of the total effect of perceived behavioral control mediated by intention or attitude was 25% (95% BCI: 10, 43) and 17% (95% BCI: 4, 31), respectively (Table 4). Therefore, the proportion of the total effect of perceived behavioral control on preventive behavior not mediated by intention or attitude was 58% (95% BCI: 30, 82), confirming the direct association between perceived behavioral control and running-related injury preventive behavior.

The proportion of the total effect of attitude mediated by intention or perceived behavioral control was 40% (95% BCI: 21, 61) and 44% (95% BCI: 20, 69), respectively (Table 4). Therefore, the proportion of the total effect of attitude on running-related injury preventive behavior not mediated by intention or perceived behavioral control was 16% and it was not statistically significant (95% BCI: −23, 52). Therefore, a direct effect of attitude on preventive behavior was unlikely, as postulated by the Theory of Planned Behavior (Fig. 1).

Discussion

Explanatory potential of the theory of planned behavior

The explained variance around running-related injury preventive behavior found in our study was higher compared to

Table 3 Bayesian mixed models investigating the Theory of Planned Behavior in the context of running-related injury prevention.

Dependent variable	Independent variable	Prior	Likelihood	Posterior	
		β (95% BCI)	β (95% CI)	β (95% BCI)	RR (95% BCI)
Model 1: *R^2 0.48 (95% BCI: 0.40, 0.55)*					
Preventive behavior	*Intercept*	–	0.73 (0.60, 0.86)	0.70 (0.58, 0.83)	2.02 (1.78, 2.29)
	Intention	0.35 (0.15, 0.54)	0.22 (0.14, 0.30)	0.24 (0.17, 0.31)	1.27 (1.18, 1.37)
Model 2: *R^2 0.48 (95% BCI: 0.41, 0.55)*					
Preventive behavior	*Intercept*	–	0.62 (0.48, 0.76)	0.59 (0.44, 0.72)	1.80 (1.56, 2.06)
	Intention	0.35 (0.15, 0.55)	0.18 (0.10, 0.26)	0.20 (0.13, 0.28)	1.22 (1.14, 1.32)
	Perceived behavioral control	0.20 (0.00, 0.40)	0.16 (0.07, 0.26)	0.16 (0.08, 0.25)	1.18 (1.08, 1.65)
Model 3: *R^2 0.49 (95% BCI: 0.41, 0.56)*					
Preventive behavior	*Intercept*	–	0.56 (0.39, 0.73)	0.51 (0.36, 0.65)	1.66 (1.43, 1.92)
	Intention	0.35 (0.15, 0.55)	0.15 (0.07, 0.24)	0.18 (0.10, 0.25)	1.19 (1.10, 1.28)
	Attitude	0.10 (0.04, 0.16)	0.08 (−0.05, 0.22)	0.09 (0.04, 0.15)	1.10 (1.04, 1.16)
	Subjective norm	0.02 (−0.04, 0.08)	0.02 (−0.03, 0.08)	0.02 (−0.02, 0.06)	1.02 (0.98, 1.06)
	Perceived behavioral control	0.20 (0.01, 0.40)	0.14 (0.04, 0.24)	0.14 (0.06, 0.23)	1.15 (1.06, 1.26)
Model 4: *R^2 0.50 (95% BCI: 0.43, 0.56)*					
Intention	*Intercept*	–	0.27 (0.11, 0.43)	0.53 (0.40, 0.66)	–
	Attitude	0.15 (0.05, 0.25)	0.61 (0.48, 0.73)	0.32 (0.24, 0.40)	–
	Subjective norm	0.06 (−0.04, 0.16)	0.10 (0.04, 0.16)	0.10 (0.05, 0.15)	–
	Perceived behavioral control	0.22 (0.12, 0.32)	0.14 (0.04, 0.24)	0.23 (0.16, 0.30)	–
Model 5: *R^2 0.61 (95% BCI: 0.55, 0.65)*					
Attitude	*Intercept*	–	0.88 (0.80, 0.96)	0.88 (0.80, 0.96)	–
	Subjective norm	0.20 (0.00, 0.40)	0.06 (0.02, 0.10)	0.06 (0.03, 0.10)	–
	Perceived behavioral control	0.30 (0.10, 0.49)	0.33 (0.27, 0.39)	0.33 (0.27, 0.38)	–
Model 6: *R^2 0.48 (95% BCI: 0.41, 0.54)*					
Subjective norm	*Intercept*	–	0.16 (−0.08, 0.40)	0.15 (−0.06, 0.36)	–
	Attitude	0.20 (0.00, 0.40)	0.29 (0.11, 0.47)	0.22 (0.09, 0.35)	–
	Perceived behavioral control	0.30 (0.10, 0.50)	0.04 (−0.10, 0.18)	0.13 (0.02, 0.24)	–
Model 7: *R^2 0.60 (95% BCI: 0.55, 0.65)*					
Perceived behavioral control	*Intercept*	–	0.31 (0.17, 0.44)	0.36 (0.23, 0.49)	–
	Attitude	0.30 (0.11, 0.50)	0.55 (0.45, 0.64)	0.49 (0.40, 0.58)	–
	Subjective norm	0.30 (0.11, 0.50)	0.01 (−0.03, 0.06)	0.03 (−0.01, 0.08)	–

The results of models 1, 2, and 3 were based on Bayesian Poisson mixed models. The results of models 4, 5, 6, and 7 were based on Bayesian linear mixed models. The non-informative prior implemented for the random effects in all models was the uniform distribution with lower and upper bounds of 0 and 10, respectively.
β: regression coefficient.
RR: rate ratio (obtained by β exponentiation from Poisson mixed models).
95% BCI: 95% Bayesian highest posterior density credible interval.
95% CI: 95% frequentist confidence interval.

Table 4 Mediation analysis investigating the influence of the Theory of Planned Behavior on running-related injury preventive behavior.

Mediator	Determinants	Natural direct effect	Natural indirect effect	Total effect	Proportion mediated
		β (95% BCI)	β (95% CI)	β (95% BCI)	% (95% BCI)
Intention					
	Attitude	0.09(0.04, 0.15)	0.06 (0.03, 0.09)	0.15 (0.09, 0.21)	40 (21, 61)
	Perceived behavioral control	0.14 (0.06, 0.23)	0.04 (0.02, 0.06)	0.18 (0.10, 0.27)	25 (10, 43)
Perceived behavioral control					
	Intention	0.18 (0.10, 0.25)	0.01 (0.00, 0.03)	0.19 (0.12, 0.26)	9 (1, 18)
	Attitude	0.09 (0.04, 0.15)	0.07 (0.03, 0.11)	0.16 (0.10, 0.23)	44 (20, 69)
Attitude					
	Intention	0.18 (0.10, 0.25)	0.02 (0.01, 0.03)	0.20 (0.12, 0.27)	12 (4, 21)
	Perceived behavioral control	0.14 (0.06, 0.23)	0.02 (0.01, 0.04)	0.17 (0.08, 0.25)	17 (4, 31)

β: regression coefficient.
95% BCI: 95% Bayesian highest posterior density credible interval.

physical activity studies (27.4%).[38] The explained variance around intention found in our study corroborates previous studies on physical activity (44.5%).[38] Therefore, using the Theory of Planned Behavior to better understand and/or modify running-related injury preventive behavior and/or intention toward such behavior seems to be reasonable and relevant.

The small indirect effects found for the association between *intention* and preventive behavior suggested that the effect of intention on running-related injury preventive behavior was unlikely to be mediated by any behavioral determinant under study. These findings seem to be unequivocal, because most of the evidence on the association between intention and behavior, regardless of the research field, corroborates our results.[9,31,38] For example, the association between intention and behavior presented a correlation coefficient of around 0.54 (95% BCI: 0.38, 0.67)[31] and 0.51 (90% BCI: 0.17, 0.85)[38] in the field of environmental behavior and physical activity, respectively.

Ajzen[9-11] highlighted that the direct association between *perceived behavioral control* and behavior is likely to emerge only when the perceived behavioral control accurately reflects actual behavior control. Therefore, the direct association between perceived behavioral control and running-related injury preventive behavior found in our study (dashed line in Fig. 1) may be explained by the possibility that perceived behavioral control accurately reflects actual behavior control toward running-related injuries.[10,39] In addition, perceived behavioral control was associated with intention to perform running-related injury preventive behavior. Most evidence corroborates our results.[9,11,13,28-30,32,38]

Attitude was the determinant with the strongest relationship with intention to perform running-related injury preventive behavior. This finding was also observed for physical activity[38] and wearing safety gear in skating[13] and cycling.[40] In other fields and contexts there was also a substantial relationship between attitude and intention.[9,30,32] Attitude also presented an indirect relationship with running-related injury preventive behavior. These findings highlight the importance, relevance, and need for considering athletes,' coaches,' and stakeholders' beliefs in sports injury prevention.[41,42]

Subjective norm was the determinant with the weakest relationship with intention to perform running-related injury preventive behavior. Most evidence on physical activity and other fields corroborates our results.[9,32,38] A possible explanation could be that, because running is an individual sport, social pressure would be less likely to influence runners' intentions to perform preventive behaviors. However, conflicting evidence also exists. Subjective norm was the determinant with the strongest relationship with intentions to wear safety gear in sports[13,40] and for girls' intentions to practice moderate to vigorous physical activity.[32] Therefore, it would be reasonable to assume that others' and/or groups' opinions relate to individual intentions toward preventive behaviors. However, scientific evidence suggests that such a relationship is likely to be stronger for girls and for intentions to wear protective equipment. This might be explained by the evidence supporting that women are more likely to have larger social support (i.e. larger networks and multiple sources of support)[43] and that wearing protective equipment may impose less barriers to behavior change than lifestyle interventions such as diet and exercise.[44]

Mediators

Our results highlight the importance of intention and perceived behavioral control as mediators of the effects of other determinants on running-related injury preventive behavior. Intention is well described as a mediator in the Theory of Planned Behavior.[9-11,25,38] A meta-analysis revealed that when including perceived behavioral control to explain physical activity behavior in the Theory of Reasoned Action (the precursor of the Theory of Planned Behavior), the association between attitude and intention was attenuated while the direct association between perceived behavioral control and behavior was statistically significant.[38] This indicated that perceived behavioral control might have mediated part of the effect of attitude on physical activity behavior.

Strengths and limitations

The strengths of this study included the novelty of investigating the relationships between running-related injury preventive behavior and its determinants and showing that the Theory of Planned Behavior might have the potential to partly explain running-related injury preventive behavior. The performed path analysis used data collected prospectively and with repeated measurements, which accounted for changes in the modifiable determinants and behaviors. Another strength is the use of previous knowledge in the data analysis, allowing for updates of these priors based on collected data (i.e. full Bayesian approach).

Being a secondary analysis of a randomized controlled trial can be considered a limitation, because this study was not initially designed to answer the research question herein addressed. However, we are of opinion that bias related to design is unlikely in this study, because the design applied (i.e. prospective cohort study) is appropriate for the study purpose.[45] The convenience sample used in our study might have included selection bias. Data were self-reported, which might have included detection bias.

The *TrailS₆* prevention program was effective in reducing the risk of running-related injuries by 13% (95% BCI: −23.3, −3.1) in six months by providing advice on the seven preventive behaviors investigated in this study.[18] The seven preventive behaviors were selected to compose the *TrailS₆* prevention program through a participatory approach using the Knowledge Transfer Scheme as a framework.[18] In the development group, there were researchers, running coaches, trail runners, stakeholders and physical therapists. Therefore, the program was evidence-based, since active researchers on the field of running-related injury prevention were part of the development process. The *TrailS₆* was also tailored to the specific context of trail running, since running coaches and the trail runners themselves participated in the development group. However, the trail runners could have adhered to the entire, part or none of the components of the *TrailS₆* prevention program. Adherence was actually considered and discussed in the effectiveness study, which considered the intention-to-treat principle.[18] We do not believe that the adherence rate would have influenced the results of the current study, since the mechanism related to the extent to which the determinants of behavior could have explained the adherence to the preventive behaviors was actually the aim of this study, and not the adherence rate itself. Nevertheless, we are glad to disclose such context for the sake of transparency and so the reader can reflect on the matter.

Perspectives

Researchers, program developers, and implementers might consider using the Theory of Planned Behavior as a relevant and useful tool in studying (by providing outcome measures), developing (social science theory to behavior change), and/or implementing running-related injury prevention programs by specifying behavioral determinants to increase adherence to prevention programs and, in turn, to enhance the effectiveness of such programs. Also, coaches, athletic trainers, and health professionals might implement measures of intention, attitude, subjective norm, and perceived behavioral control to understand and/or partly explain preventive behavior in practice. For example, physical therapists might consider changing the runners' and/or coaches' beliefs (represented in the Theory of Planned Behavior as attitudes) by providing educational strategies to influence their intention to perform preventive behaviors and, in turn, influencing/changing actual running-related injury preventive behavior.[41,46]

Conclusions

The Theory of Planned Behavior presented the potential to explain half of the variance around preventive behavior and intention toward running-related injury prevention. Intention and perceived behavioral control were directly associated with running-related injury preventive behavior. However, a quarter of the total effect of perceived behavioral control on running-related injury preventive behavior was mediated by intention. Forty percent and 44% of the total effect of attitude on running-related injury preventive behavior was mediated by intention and perceived behavioral control, respectively. Attitude, subjective norm, and perceived behavioral control were all significantly associated with intention. Therefore, the Theory of Planned Behavior may be a relevant and useful tool for successful implementation of running-related injury prevention programs.

Conflicts of interest

LH, CSV, and EV declare that they have no conflict of interest of any nature. WvM declares for the avoidance of doubt that he is director of VU University Medical Center Amsterdam spin-out company Evalua Nederland B.V. (http://www.evalua.nl), and non-executive board member of Arbo Unie B.V. (http://www.arbounie.nl). Both companies operate on the Dutch Occupational Health Care market, and they have no relationship of any nature with this study or with the *TrailS*$_6$ intervention.

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