Sprint-Specific Training in Youth: Backward Running Versus Forward Running

1 Title: Sprint-specific training in youth: Backward running versus forward running training on speed and power measures in adolescent male athletes

Running head: Sprint-Specific Training in Youth: Backward Running Versus Forward Running

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ABSTRACT
This study compared the effects of two sprint-specific training programs against the natural development of speed, power and stiffness in a group of adolescent males. Forty-three male adolescents (aged 13-15 years) were randomly assigned to one of two training groups; backward running training (BRT = 26), or forward running training (FRT = 17). A physical education class (n=24) of similar age constituted a control group (CON). Both training groups performed running sessions matched for distance and intensity bi-weekly for eight-weeks. Parametric and magnitude-based inferences were used to analyze within group (pre-post measures) and between group (gain scores) for 10 m, 10-20 m and 20 m sprint times, vertical countermovement jump height (CMJ) and vertical leg stiffness. Both running groups significantly improved ($p \leq 0.05$) in all performance tests from pre- to post-training, with effect sizes ranging from -1.25 to 0.63. When the groups were compared the BRT and FRT groups improved significantly ($p \leq 0.01$) on all sprint performances and stiffness relative to the CON. The BRT group demonstrated favorable effects for 10 m and 20 m sprint performances (ES = -0.47 and -0.26, respectively) and CMJ height (ES = 0.51) compared to the FRT group. These results demonstrate that forward and backward sprint-specific training programs enhance speed and power measures more than natural development in adolescent male athletes. Furthermore, the greater training responses in sprint performance and CMJ ability indicate that BRT is a useful tool for improving concentric strength and power and may be classified as a sprint-specific training method.

Key Words: countermovement jump, youth, sprint training, transfer, stiffness
INTRODUCTION

Sprint performance over short distances has been identified as a key characteristic of successful young athletes around the time of their adolescent growth spurt (19). Boys commonly experience their adolescent development between 12 and 16 years of age (3). Given the importance of sprint ability in sport and suggestion that speed development can be optimized during adolescence (15), it is no surprise that a myriad of specific and non-specific training methods have been developed to enhance neural and structural characteristics associated with sprint performance in adolescents (7, 18). Sprint-specific training refers to free sprinting (i.e. straight line sprinting with passive recovery), resisted sprinting or assisted sprinting, while non-specific sprint training corresponds to other methods, such as strength, power or plyometric training (31, 32). An abundance of research is available highlighting the benefits of non-specific training methods on sprint performance and underlying determinants of speed, such as lower body power and stiffness (2, 16, 25), yet the optimal development of speed and power measures in adolescent male athletes using sprint-specific training methods requires further understanding.

Researchers have reviewed the effectiveness of sprint-specific training on boys sprinting ability, concluding that free sprinting is a beneficial method for enhancing short-sprint speed up to 20 m with moderate to large effects (24, 31). From these two reviews a total of six studies were identified which measured the effects of straight-line free sprint training on running performance. Although the current reviews provide a comprehensive overview of the available scientific literature, the effects of anecdotal training methods yet to be empirically scrutinized remain unknown. For example, backward running (BR) has been used as part of specific training procedures in a variety of athletic sports (11, 37). However, to the authors’ knowledge the effects of BR on forward sprint performance in adolescent athletes is absent from literature.
Like forward running (FR), BR occurs in bursts during many over-ground sports (e.g. soccer, rugby, American football, and most racquet sports) (22). A recent review of BR by Uthoff, et al. (37) highlights the immediate and long-term effects of BR on athletic performance. Sports warm-up programs such as the “FIFA 11+”, “Harmoknee” and “Prevent Injury and Enhance Performance” include BR to prepare adolescent athletes for the demands of competition, reduce injury rates (28, 33) and enhance performance (1, 27). The use of BR has been recommended in adult sports training programs due to its ability to improve power output (36) while concomitantly reducing stress on the knee joint (29) compared to FR. Furthermore, it has been theorized that training adaptations from BR may transfer to FR tasks (11, 20). Evidence for this effect has been reported in adult populations (34, 35). For example, BR training has been shown to improve change of direction performance (34, 35), increase foot speed in a ladder test (35) and maintain 20 m sprint performance times (35). While previous findings are promising in adults, it is unknown how these types of training adaptations might transfer to adolescent athletes. Given that BR appears to be a method which promotes injury prevention, increased power output and performance transfers to FR tasks, the lack of research attempting to quantify the effects of BR on these outcomes in adolescent athletes is surprising.

Most research into the trainability of speed and power in adolescent athletes has explored the effectiveness of non-specific sprint training methods. Methods such as strength training and plyometric training have been shown to enhance speed and lower body power and force characteristics (2, 16). Similarly, sprint-specific training methods are known to improve sprinting performances in adolescents (24, 31). Although, relatively few studies are available on the trainability of speed in young athletes using free FR running training or the effects of this type of training on lower body power and force measures in pediatric populations. Further,
it is unknown whether BR training influences performance outcomes and if these adaptations transfer to forward sprint ability in adolescent athletes. Therefore, the primary aim of the current research was to explore the effects of free BR and FR training programs and quantify the potential training related adaptations these methods promote on sprinting performance and underlying determinants of speed, such as leg stiffness and lower body power in adolescent male athletes.

METHODS

Experimental Approach to the Problem

A cluster randomized control trial was conducted to quantify the effects of eight weeks of bi-weekly progressive running training, either forwards or backwards. To determine the effectiveness of the sprint-specific training programs on speed and power measures, sprinting ability, jumping performance and vertical leg stiffness were tested pre- and post-training. Boys enrolled in an athletic development program at their school were divided into a backward running training group (BRT; n = 26) and a forward running training group (FRT; n = 17). A control group (CON; n = 24) of the same age and physical characteristics was recruited from the school to assess the effects of natural growth on the selected performance measures. The CON participated in their school’s normal P.E. curriculum, but not any structured training program. Habituation sessions for the performance tests occurred in week one, baseline testing was administered in week two, supervised training was performed for the following eight weeks and finally post-testing was concluded in week eleven. Quantitative analyses were conducted to test scores from pre-to post-training, while qualitative meaning of any observed changes in the independent variables were examined using inferential statistics.

Subjects
A group of sixty-seven adolescent males from a boys’ high-school volunteered to participate in this study. Forty-three subjects were recruited from their school’s athlete development program and randomly assigned to either a backward running training group (BRT; n = 26) or a forward running training group (FRT; n = 17). The remaining subjects were recruited from a physical education (P.E.) class, where they participated in their school’s normal P.E. curriculum, serving as a control (CON; n = 24) to compare the training effects on the performance measures to those of normal maturation. The athlete development program at the school was an option for students who wished to participate in organized training in place of their normal P.E class. Non-invasive anthropometric measurements were used to calculate maturity offset using an equation developed by Mirwald, et al. (21). There were no significant differences between groups for physical characteristics or maturity offset. Table 1 outlines a summary of the subject’s characteristics.

Subjects were included in this study if they were males between the ages of 13 and 15 years, enrolled in a public high-school and free of any medical issues or injuries which may have compromised their participation or performance. Subjects were excluded if they did not meet the above criteria or failed to adhere to the training program with above 80% attendance. After being informed about the benefits and risks of participating in this research, written consent was provided by all parents/guardians and assent was obtained from the boys. All procedures were reviewed and approved by the Institutional Research Ethics Committee.

**Table 1:** Subject characteristics (mean ± standard deviation).

Key: CON Control group, BRT Backward running training group, FRT Forward running training group.
Testing and Procedures

Two baseline testing sessions and a post-training testing session were conducted at the same time of day, on the same wooden sprung floor, in the same indoor school gymnasium, using the same testing order for all performance tests. The participants wore the same clothing and footwear for each testing and training session, were asked to avoid any strenuous activity during the 12 hours preceding each session and maintain their normal dietary intake before and after each session. The subjects participated in two orientation sessions, separated by three days, to habituate themselves with the equipment, experimental procedures and movements two weeks before the study commenced. The participants’ anthropometric measurements (height, seated height and body mass) were obtained during the first testing session. Thereafter, each participant performed a 15-minute standardized warm-up consisting of skipping, jumping, FR, BR and sideways running progressively increasing in intensity over 20 m, interspersed with dynamic stretching of the lower limbs. Each testing session was used to determine the participants’ 10 m, 10-20 m and 20 m sprint times (s), countermovement jump height (cm) and vertical leg stiffness. Each performance test was completed twice by all participants in every group during each testing session. Five minutes of passive recovery was given between each test. Average performance data for each test was used for analysis. Baseline testing took place twice to establish the reliability of the variables with the examined population before the eight-week study. Coefficient of variation (CV) was computed to determine interday reliability of the two pre-test performances: 10 m sprint time (CV = 2.83%), 10 – 20 m sprint time (CV = 0.23%), 20 m sprint time (CV = 1.76%), vertical CMJ (CV = 4.24%) and hopping tests (CV = 4.34%).

Speed, Power and Stiffness Testing
Sprinting performance times over 20 m and splits from 0-10 m and 10-20 m were evaluated using SpeedlightV2 wireless dual-beam photocell timing gates (Swift Performance Equipment, Australia). Timing gates were placed 1.5 m apart at the start, 10 m and 20 m distances, with photocell heights set at 92.5 cm (top beam) and 68 cm (bottom beam) to correspond with approximately the center of mass of the participants. Participants were instructed to start in a split stance with their lead leg 50 cm behind the first timing gate and toes of the back foot in line with the heel of the front foot. No rocking or false steps were permitted prior to starting.

Sprinting was encouraged to be completed with maximal effort for each trial. Sprint-running performance up to 20 m has shown good test-retest reliability in adolescence athletes (CV = 1.3 – 2.0%) (8).

Bilateral vertical countermovement jump (CMJ) height with full arm action was used to assess lower-body power. A Vertec vertical jump tester (Sports Imports, Columbus, OH, USA) was used to quantify jump height. The lowest vane was individually adjusted so that it corresponded to within 0.5 cm of each participant’s maximal standing reach height (26). Participants were requested to use their dominant hand to displace the highest possible vane with an overhead arm swing at the highest point of their jump. Height was determined from the Vertec system as the number of vanes displaced above the original standing reach height to the nearest 1.27 cm. Jump height was then calculated by subtracting the standing reach height from the maximal jump and reach height determined from the highest displaced Vertec vane (10). Between each attempt, all vanes were repositioned so that multiple trials could be recorded.

Leg stiffness was measured using a field based submaximal hopping test (17). Participants were asked to hop bilaterally for 20 consecutive hops on a portable contact mat (Fitness Technology, Australia) at a frequency of 2.5 Hz. Participants were instructed to minimize foot-
ground contact time while hopping to an auditory signal produced via an electronic metronome. Ten consecutive hops closest to the designated frequency were used for analysis. Absolute leg stiffness (kilonewtons per meter; \(KN\cdot m^{-1}\)) was calculated by modeling the vertical ground reaction force, based on the flight and contact time during hopping (6). The measures of body mass, contact and flight time were entered into an equation proposed by Dalleau, et al. (6) in Equation 1, which has been shown to be a valid and reliable calculation in adolescents (17).

Equation 1.

Vertical leg stiffness = \(\frac{M \times \pi (T_f + T_c)}{T_c^2 (\frac{T_f + T_c}{\pi} - \frac{T_c}{4})} / 1000\)

Where M was the body mass and \(T_c\) and \(T_f\) were ground contact time and flight time, respectively.

Running Training Program

Running training was conducted twice a week for eight-weeks on non-consecutive days. The running program was conducted in place of the athletes’ normal physical education curriculum, and in addition to their regular sport training (i.e. typically two training session and one competition game a week). The running training program involved participants performing linear running over a range of intensities either forward or backward. Each training session was conducted after a standardized progressive warm-up resembling the one used during testing. Progressive overload principles were incorporated into the program by increasing the overall intensity of the session via auto-regulated running speed and running distance (see Figure 1). The intensities of slow, moderate and fast correspond to approximately 20 - 45%, 50 - 75% and ≥ 95% of maximal effort, respectively. These speeds were chosen to reflect common running intensities which young male athletes are capable of self-selecting using autoregulation (38). Table 2 outlines the repetitions by intensity over the prescribed distances for each training
session. Equal volume and intensity were prescribed for both the BRT and FRT groups. A duration of eight-weeks was chosen for this study to exemplify how a running training program can be implemented and assessed over a typical school term in a high-school athlete development program.

PLEASE INSERT TABLE 2 ABOUT HERE

**Table 2.** Eight-week running program for BRT and FRT groups. ABOUT HERE

Key: BRT Backward running training group; FRT Forward running training group.

PLEASE INSERT FIGURE 1 ABOUT HERE

**Figure 1.** Volume by intensity per session for duration of running program.

Due to the novelty of high-speed BR, special attention was focused on correct BR technique by the means of demonstration and verbal feedback in the early sessions. Technical characteristics of BR stressed during training are presented in Table 2. The FRT group also received specific technical instructions, such as; 1) “knee-up and toe-up”, 2) “drive your arms from cheek to hip”, 3) “strike the ground with the ball of your foot” and 4) “strike the ground under your hips and push back”.

PLEASE INSERT TABLE 3 ABOUT HERE

**Table 3.** Technical cues for BR emphasized for the BRT group.

BR = backward running; FR; forward running; BRT = backward running training; Swing leg = the leg not in contact with the ground while running.

**Statistical Analysis**
The statistical analyses were performed using Microsoft Excel (version 15.28; Microsoft, Seattle, WA, USA) and SPSS 24.0 for MAC OS (SPSS, Inc, Chicago, IL, USA). The data was explored using histogram plots, and normality of the distribution for all variables was tested using Kolmogorov-Smirnov test. Homogeneity of variance was tested using the Levene’s test. Thereafter, descriptive statistics were calculated and reported as mean and standard deviations (SD). Within-group differences between pre- and post-training for all performance variables were analyzed using paired t-tests. Within-group percentage change and effect size were calculated to quantify the magnitude of the performance change in each group’s performance tests. Within-group ES was calculated by dividing the difference between the mean performance change (i.e. post-training results – pre-training results) by the pooled SD for each performance variable (5). The smallest worthwhile individual change (SWC = 0.2 * SD) was calculated on the pooled SD of both pre-training session scores for all groups and converted to a percentage for each performance variable, where changes were deemed small (0.2 * SD), moderate (0.6 * SD) or large (1.2 * SD) (13). Training-related effects between groups were assessed using a one-way analysis of variance (ANOVA) on the change score (mean difference from pre-training to post-training) for each performance variable, similar to Winwood and Buckley (40). Sidak post-hoc comparisons were applied if a significant F value was observed to locate pairwise differences. The intervention ES was calculated by dividing the difference between groups’ change scores by their pooled SD for each performance variable. Classification of ES was as follows: trivial (< 0.20), small (≥ 0.20 to < 0.60), moderate (≥ 0.60 to < 1.2) and large (≥ 1.2) (5, 12). Significance was accepted at the p ≤ 0.05 level and 95% confidence intervals (CI) were used for all analyses.

RESULTS
Performance testing data for the BRT, FRT and CON groups are presented in Table 3, including within-group changes from pre- to post-training and between-group differences of the mean changes. The within-group analysis revealed that BRT elicited significant changes \((p \leq 0.01)\) in sprint times, CMJ height and leg stiffness with improvements ranging from small to large from pre- to post-testing. Significant differences \((p \leq 0.05)\) were reported following FRT for sprint times, CMJ performance and leg stiffness, with beneficial effects ranging from small to large. The CON group reported mixed significant results, evident by small detrimental effects on sprinting performance \((p \leq 0.05)\) over all distances and small beneficial effects on CMJ height \((p \leq 0.05)\).

The BRT group had the highest relative number of individual responses above the SWC for 10 m times \((96\%)\), 20 m times \((96\%)\), CMJ height \((80\%)\) and vertical leg stiffness \((72\%)\). The FRT group demonstrated the greatest relative number of responses above the SWC for 10-20 m times \((56\%)\). Performance gains in CMJ height were experienced in 58\% of the CON group. Moderate to large gains were experienced in 96\% of the BRT group for 10 m and 20 m performance and 53\% to 65\% of the FRT group, respectively. Over half of the BRT \((52\%)\) and FRT \((50\%)\) groups experienced moderate to large gains in leg stiffness while just over a quarter were over the SWC threshold in the CON group \((27\%)\). Note that the SWC for sprinting performance is negative to reflect that decreases in sprint times are associated with improvements in performance. Figure 3 and Figure 4 provide graphical references illustrating the individual percentage changes relative to the SWC detected for the BRT, FRT and CON groups for sprinting performances and lower body power and stiffness measures, respectively.
**Table 4.** Descriptive performance testing results with mean (standard deviation) BRT (n = 26), FRT (n = 17) and CON (n = 24) groups including within- and between-group changes from pre- to post-training.

Key: FRT Forward running training; BRT Backward running training; CON Control group; M mean; SD Standard deviation.

* Significant (p ≤ 0.05), † Significant (p ≤ 0.01) and ‡ significant (p ≤ 0.001) for within-group pre- and post-test variables.

C Effect towards CON; F Training effect towards FRT; B Training effect toward BRT.

When the mean change scores between the groups were compared, statistically significant main effects were reported for all performance tests (p ≤ 0.001). Compared to the CON group, significant differences (p ≤ 0.001) were reported to be favorable for BRT on all performance tests, where large changes occurred for sprint times, and small to moderate changes were seen in CMJ height and vertical leg stiffness, respectively. The FRT group displayed significant improvements (p ≤ 0.01) compared to the CON group in sprinting ability and vertical leg stiffness, where small to large effects were present for each performance test, respectively. Comparisons between training groups reported significant differences (p ≤ 0.05) with small effects for 10 m and 20 m sprint times and CMJ height in favor of BRT over FRT.

**PLEASE INSERT Figure 3.** Graphical illustration of individual percentage change for sprinting performances over 10m, 10-20m and 20m from pre- to post-training by group.

- Small response (SWC =0.2); - - - - - Moderate response (MWC = 0.6); - - - - - - - - - Large response (LWC = 1.2); FRT Forward running training group; BRT Backward running training group; CON control group; SWC Smallest worthwhile change. ABOUT HERE
PLEASE INSERT Figure 4. Graphical illustration of individual percentage change for countermovement jump height, vertical leg stiffness and sit and reach performance from pre- to post-training by group.

--- Small response (SWC = 0.2); ---- Moderate response (MWC = 0.6); ------ Large response (LWC = 1.2); FRT Forward running training group; BRT Backward running training group; CON control group; SWC Smallest worthwhile change.

DISCUSSION

The purpose of this research was to understand the effects of BR and FR training programs on speed and power measures in adolescent males. The present study is the first to investigate the effects of performing free BR or FR training on short-sprint speed and power measures in adolescent athletes. The major finding of the present study was that both running groups improved sprinting performance and vertical leg stiffness compared to the CON group who participated in normal physical education curriculum. Moreover, BRT appeared to provide the greatest performance benefits for CMJ height and 10 m and 20 m sprint times compared to the CON and FRT groups.

Findings from this study revealed training related improvements in short sprinting performance up to 20 m for both FRT and BRT groups compared to the CON group. This is in agreement with previous reports that free sprint training enhances sprint performances up to 20 m more than natural development in adolescent males (23). Additionally, the current research found that BRT provided greater gains in sprinting performance over 10 m and 20 m compared to FRT. This finding is in line with a previous study which concluded that BR training was more effective at maintaining FR sprint ability than FR training in a group of 17 trained netball players (35). This is the first study to demonstrate that BR can be used as a training method to
significantly enhance FR sprint performance. An explanation for this finding could be that both
directions of locomotion are generated by the same basic neural mechanisms (9, 14, 20).
Neurological adaptations are known to occur in response to periods of sprint training (30). By
training one direction of running, neurological adaptations may result for both BR and FR (11,
20). Therefore, BR may be classified as a sprint-specific training method.

A higher number of participants in the BRT and FRT groups experienced adaptations greater
than the SWC compared to the CON group, with all but one participant in the BRT group
experiencing moderate to large gains in 10 m time. While improvements in 10 m and 20 m
sprint performance were reported following both the BRT and FRT programs, it is important
to distinguish that gains in 20 m performance were primarily a result of increased speed over
the first 10 m. This is especially true for the BRT group, who increased performance more over
10 m than 20 m compared to the CON and FRT groups. Although, the present study
demonstrated that improvements in 10 m sprint performance have subsequent benefits over
longer distances up to 20 m. It appears that sprint-specific training, either forward or backward,
increases early acceleration over 10 m to a greater extent than late acceleration, or performance
over 20 m, based on the relatively larger effects identified from pre- to post-training. As BR
is known to be achieved through higher step frequencies and lower step lengths compared to
FR (37), increases in sprinting performance may be a result of alterations in step kinematics
which are representative of early accelerative sprinting (39), i.e. 0-10 m. However, further
research using floor level optical timing systems or video are required to substantiate this posit.

The current study revealed that BRT yielded moderate effects for CMJ performance (↑10.2%),
whereas FRT had trivial effects on jumping ability (↑2.8%). Moreover, over half of the BRT
group demonstrated a moderate to large worthwhile change in CMJ height. The larger increase
in CMJ height displayed in the BRT compared to FRT group in the present study contradicts a previous report by Terblanche and Venter (35) which found female netball athletes aged 19-20 years improved CMJ performance more following FR training (↑2.61%) compared to sport-specific BR training (↑0.25%). Differences between the present study and those of Terblanche and Venter (35) could be related to either the technical running model used or the amount of work performed during training. Terblanche and Venter (35) applied maximal effort BR in a sport-specific program, mimicking FR drills, with limited mention of BR technique, distance or speed. The present study, in contrast, used principles of overload to progress BR up to maximal intensity, as a specific training drill where biomechanical components were emphasized via a combination of demonstration and verbal feedback. Therefore, the effect of BR training may be influenced by the quality and attention to direction-specific running mechanics. Ultimately, training BR appears to have favorable transfer to FR and movements related to lower body power, i.e. CMJ height.

The significant improvement in vertical leg stiffness following BRT (↑10.6%) and FRT (↑12.4%) observed in the current study demonstrate the ability of free sprint-specific training methods to enhance stretch-shortening cycle function in adolescent male athletes. These results are comparable with previous reports that leg stiffness in pediatric populations are enhanced by up to 8% following non-specific sprint training (i.e. plyometrics) (16). This is important considering increased leg stiffness has been associated with higher maximal sprinting speeds in adolescents (4). The present study demonstrated that both running programs were equally effective at inducing performance gains in stiffness when compared to the CON group. This finding is promising because it provides evidence that BR and FR increase vertical leg stiffness more than a traditional physical education curriculum in adolescent athletes. Given the relationship between stiffness and maximal velocity sprinting, it can be postulated that either
direction of sprint-specific training may be used to increase the maximal sprinting speed in young athletes.

Readers should be cognizant that the participants were performing a variety of sport trainings outside of school which were not quantified and may have had some influence on the training adaptations observed in this study. Nevertheless, this study demonstrates that BR and FR training can be implemented twice a week in a high-school athlete development program intended to improve physical performance in adolescent male athletes. The training gains from BR for sprint performance, leg stiffness, and CMJ ability were comparable to, or greater than, FR. These findings suggest that BR is similarly beneficial to other modes of sprint training for improving sprinting and lower body performance measures and may be classified as a sprint-specific training method. However, future research should consider using DEXA scanning to determine body composition changes and help give more insight into the nature of adaptations which take place over periods of BR training. While this study is limited to male athletes mid-PHV, it provides a snapshot of gender- and maturity-specific adaptations from sprint-specific training programs compared to a traditional physical education curriculum in adolescent boys. Such findings are important considering the lack of published data related to the effects of BR and specific FR sprint training in boys. With the recent upsurge in scientific attention aimed at optimizing sprint speed in young athletes, additional training studies are necessary to understand the mechanisms responsible for adaptations related to free and resisted BR and FR in pediatric populations.

**PRACTICAL APPLICATIONS**

Progressive high-speed BR is recommended as a safe and effective training method for improving athletic performance in adolescent males following sufficient practice and
instruction. Speed and strength coaches aiming to optimize the athletic potential of adolescent athletes should consider the following points when implementing sprint-specific training into the training programme of their athletes:

- Training adaptations from BR transfer to FR sprint ability and underlying determinants related to fast FR speeds in mid-adolescent boys.
- Both BRT and FRT can be used to improve sprinting performance, jumping height and leg stiffness in adolescent athletes.
- Implementing BR into a training program provides a novel stimulus that appears particularly beneficial for improving performance tasks heavily reliant on concentric strength and power.
- Regardless of running direction, coaches should pay particular attention to the technical demands of running movements and be cognizant that effort and intensity may moderate training responses to sprint-specific training methods.

Acknowledgements

We would like to extend our gratitude to Director of Sport, Physical Education teachers and young athletes who dedicated their time to participate in this study. Special thanks to Brad Fleming for his assistance in testing and organizing training groups.
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