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LITERATURE REVIEW

Single-Case Research Design: An Alternative Strategy for Evidence-Based Practice

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Objective: The trend of utilizing evidence-based practice (EBP) in athletic training is now requiring clinicians, researchers, educators, and students to be equipped to both engage in and make judgments about research evidence. Single-case design (SCD) research may provide an alternative approach to develop such skills and inform clinical and pedagogical practices. The purpose of this paper is to review the literature related to SCD and its potential contributions to EBP in athletic training.

Data Source(s): We searched PubMed, CINAHL, Proquest Dissertation and Theses, and Google Scholar using terms "single case design", "single subject design", "within subjects", and combined search terms of "single case design AND athletic training, AND allied health, AND medicine, AND nursing".

Data Synthesis: Textual support for the use of SCD in athletic training and a brief review of literature pertaining to: general features, strengths, limitations, and design options commonly associated with the use of SCD.

Conclusions: Use of SCD in allied health professions is limited, with fewer studies in athletic training settings. Low awareness and misinterpretation of SCD may be contributing to the low use of SCD in athletic training research. The key characteristics of SCD make it appropriate for use in clinical and educational settings and may provide clinicians, educators, and researchers an alternative tool for the development of evidence necessary to engage in evidence-based practice.

Key Words: Single subject methods, within subjects, assessment and evaluation

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Single-Case Research Design: An Alternative Strategy for Evidence-Based Practice

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The National Athletic Trainers' Association (NATA) most recently published the fifth edition educational competencies[1] for the preparation of future athletic trainers. Implicitly stated, and indirectly referred to, throughout the competencies is an increased emphasis on the use and development of evidence-based practice (EBP). The concept of EBP, while relatively new to athletic training, is not new to health care or allied health professions, with the concept dating back as far as the 19th century.[2] Evidence-based practice entails the integration of clinical expertise, acquired through clinical practice, with the best available external clinical evidence, derived from systematic research, and the values of the patient, which vary based on the individual, the situation, and the environment.[2] The recent emphasis on the use of EBP in clinical settings has prompted a need for clinicians, educators, and students to engage in or utilize systematic research to improve clinical practice. While randomized control trials are often considered the gold standard of systematic research, alternate approaches are available that can assist in clinical decision making. Single-subject research design, also referred to as single-case design (SCD) offers strategies to inform clinical decision making as well as serves as a research tool.[3] Single-case design is appropriate for use in athletic training due to its ease of use for clinical decision making and as a research design option.

The following sections will provide support for the use of SCD in athletic training and briefly review the literature related to: (1) the historical perspective of SCD, (2) the fundamentals of SCD, (3) the advantages and limitations of SCD, (4) various design options, and (5) the use of SCD in athletic training.

HISTORICAL PERSPECTIVE

In the late 19th and early 20th centuries, the intensive investigation of the individual was the accepted method of research in psychology and physiology.[4] Investigators such as Ebbinghaus, Pavlov, and Thorndike[4] were noted for their use of 1 or a few subjects at a time, consistent with a majority of others. Generally descriptive in nature, these studies did not, however, control potential confounding variables, and as a result, the effectiveness of treatments was often exaggerated or poorly substantiated.[5] By the 1930s, journal publications reflected a shift from small sample studies lacking statistical analyses to larger sample studies including statistical analyses.[4] By the late 1940s, an increase in the use of group-comparison designs further discredited the intensive study of individuals.

During the 1950s and 1960s, limitations of group-comparison design for use in clinical research were revealed. First, the results of group comparisons were of minimal value to those practicing due to variations in individual treatment effects. Second, practical issues of time, expense, and feasibility of developing an appropriate group-comparison study, as well as the ethical issue of withholding an effective treatment from a control group, contributed to a renewed interest in the individual throughout the 1960s and 1970s.[5] These issues continue to serve as limitations to group-comparison designs. Despite positive attitudes toward the implementation of EBP, translation of new evidence into clinical practice, the availability and accessibility of relevant information, and personal limitations to the implementation have been identified as barriers to both clinical and educational use of EBP in athletic training, despite a clear recognition of the value and importance.[6–9] These barriers, while minimal, highlight the need for alternative approaches to develop the evidence necessary for improving clinical and educational practice and patient outcomes.[4,6–9]

The foundation of SCD lies in the experimental analysis of behavior.[7] Three main characteristics defined Skinner's research,[7] which remain in contemporary SCD. First, the frequency of performance of a behavior was the dependent variable (DV). Second, 1 or a few subjects were studied. Third, visual analysis, not statistical analysis, of the data was used to determine the effects. Based on the use of frequency as a continuous measure of behavior, changes in performance could be detected when conditions were altered when the same behavior was observed over time. The connection between operant conditioning research and experimental analysis of behavior contributed to the development of applied behavioral analysis (ABA) and continued usage of SCD.[4]

Applied behavioral analysis emerged from Skinner's experimental analysis of behavior and operant conditioning to examine a wide variety of applied settings and populations.[4,10,11] Applied behavioral analysis research focuses on socially and clinically important behaviors in areas such as education, psychology, crime, and others, but has also been used in a myriad of settings and populations, including occupational therapy, physical therapy, and medicine. The primary methodology used to investigate techniques to change behavior has consistently been SCD.

FUNDAMENTALS OF SINGLE-CASE DESIGN (SCD)

The goal of research, in general, is the ability to draw inferences about the relations between and among variables and be able to replicate the findings. These objectives remain the same in SCD, exploring the effects of various independent variables (IV) on the DV, generally behaviors.

Single-case study design has several essential features, regardless of the specific design selected (design options discussed below): (1) identification of a baseline measure, (2) continuous and repeated measurement of the DV, (3) manipulation of the IV, and (4) replication of the intervention effects within the same subject over time, allowing the subject to serve as his or her own control.[4,12] Continuous assessment throughout the duration of the study serves as the foundation for drawing inferences about the treatment effects and allows for patterns in performance to be detected under various conditions.[13] Comparisons of performance are made as

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conditions are manipulated over time.[4,12] The replication of the effects of the treatment allows description, prediction, and testing of predictions throughout the investigation.[4]

Several other features are common in SCD investigations, but are not considered essential to the methodology. First, SCD investigations generally focus on 1 or a few (eg, n = 3 or n = 4) subjects. The actual number of subjects, however, is dependent upon the design type, the research question(s) to be answered, and the operational definition of the DV. Single-case study design can be used to compare the effects of a treatment on multiple individuals or groups (ie, classes, schools, families) or may be used to monitor compliance with a safety rule within the clinical setting (ie, turning on a whirlpool motor prior to submersion), rendering the actual number of subjects irrelevant. In each situation, the behavior being measured and the design of the study determine the number of subjects. Second, single-case research data are often drawn from direct observations of performance.[4] The historical roots of SCD from psychology and ABA have influenced SCD to maintain discrete measurement of frequency of behavior or a derivative thereof. However, psychological measures[14,15] and self-report data[16] have been reported. Thirdly, visual inspection of the data to evaluate treatment effects, rather than statistical analyses, is the primary method of evaluation. While visual comparison of behavior within, between, and across conditions for changes in level, trend, and/or variability of the data remains the predominate form of data analysis, statistical analyses have been used as a supplement to data analysis in SCD.[12] A thorough description of the use of statistical analyses in SCD is available in Wolery and Harris[12] and Reboussin and Morgan.[17] Finally, SCD has historically been used in investigations related to psychology and ABA, despite there being no essential connection. Any situation in which the goal is to influence or modify behavior (eg, compliance with rehabilitation or increase feedback to an athletic training student) or empirically evaluate an intervention (eg, the effect of a rehabilitation program on range of motion, a treatment package to decrease pain, a treatment package to increase proprioception) may benefit from the use of SCD.[4] One of the major advantages to the use of SCD in athletic training is the variety of treatments or interventions that could be examined using SCD.

Data Analysis

The visual analysis of SCD research relies on graphical depiction of the data, the use of descriptive statistics, and the ability to address questions related to changes in data patterns.[4,11,12] The effect of a treatment is determined through changes in level, trend, and/or variability (Figure 1A through C), with data collected in either a baseline phase or an experimental or intervention phase.[12] The 2 questions which must be answered when analyzing single-case research data visually are, (1) is there a change in the data pattern, and (2) do the changes correspond with the manipulation of the IV (or the introduction of the treatment or treatment protocol)? In other words, do the data change when, and only when, the treatment was introduced?[12] These questions should be directed at changes within experimental conditions (ie, within the baseline period) and between experimental conditions (ie, from baseline to experimental phase 1). Changes noted within an experimental condition may indicate threats to internal validity. Threats to internal validity (eg, history, maturation, instrumentation, statistical regression, and diffusion of treatment) must be ruled out in order to draw accurate inferences regarding the treatment. The pattern of data, continuous assessment of the dependent variable (across conditions and over time), and adherence to the operational definitions of the dependent variable and the treatment package have been suggested to reduce the plausibility of these threats and increase the internal validity.[4] Internal validity of the treatment is established when changes in behavior between phases are evident and when they correspond with the implementation or removal of a treatment. However, in most SCD designs, these changes must be consistently replicated across several experimental conditions to demonstrate an effective treatment.

Claims of external validity and generalization of the results, however, cannot be made within 1 specific SCD investigation, but rather occur from replication (across other subjects, settings, and/or behaviors) or through confirmatory group designs once a treatment package has shown promise through successful replication.[4,12]

Level (Figure 1A) refers to the absolute value of an observed behavior.[11] Between experimental conditions, level is defined as the "relative value of the data pattern on the dependent variable."[12(p447)] Changes in level within a baseline phase of an intervention may indicate an environmental variable is having an effect on behavior. Treatment implementation is typically not recommended if this occurs. This is potentially problematic in athletic training as time heals all wounds, and patients' conditions will generally improve, even if no treatment is initiated. However, the rate of improvement within the phase may be higher once a treatment has been implemented, allowing the effects of treatment to be elucidated. Change in level within a condition is determined by calculating the difference in absolute values of the observed behavior between the first and last data points within the condition or by comparing the difference between the median value of the first 3 data points and the final 3 data points within the condition.[11]

Data are also evaluated using the overall level of performance between conditions,[11] with mean and median lines providing some assistance in examination. However, relying solely on mean and median lines to determine experimental control may lead the reader to overlook variability and trend masked by these features, thus contributing to erroneous interpretation.[11] Changes in level between experimental conditions may also be used to determine the latency, or speed, of change once the treatment was initiated.[4]

Trend (Figure 1B) refers to an overall direction of a data path.[11] Trend may be described in terms of direction (increasing, decreasing, or zero), magnitude, and the variability around the trend.[11] Multiple methods of calculating trend have been described,[11] with caution being suggested in the interpretation of data patterns. The characteristics of level and trend should be viewed simultaneously, as each point in the data series contributes to both.[11] Additional techniques for analyzing trend include the semi-average method, the least squares method, the median slope procedure, and the split-middle method.[12] See Wolery and Harris[12] for a detailed description of the specific steps necessary to calculate the split-

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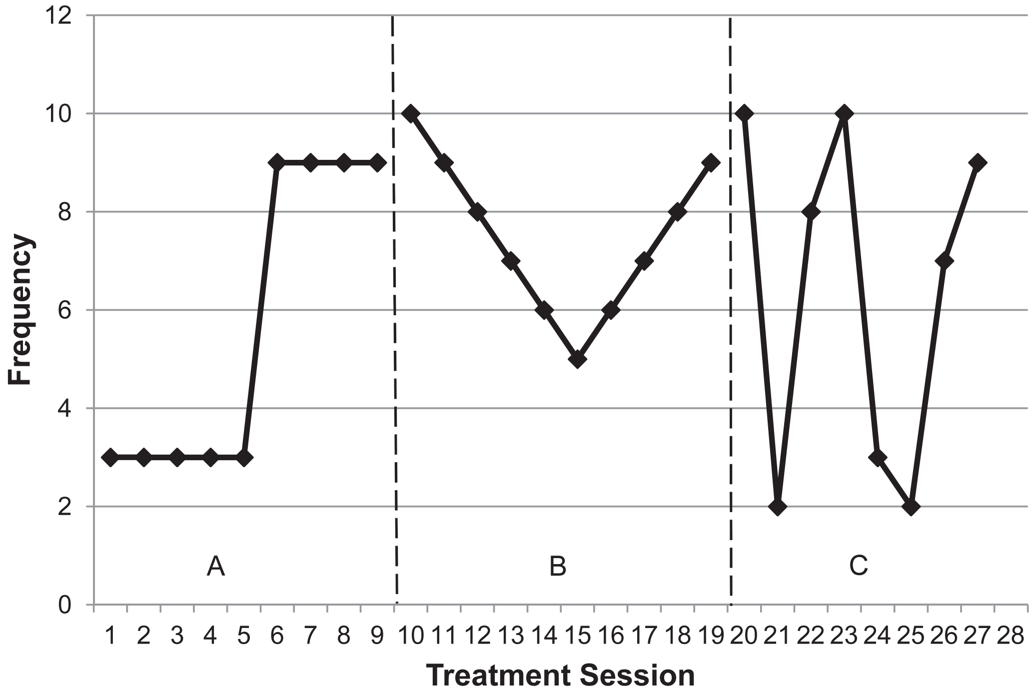
Figure 1. Visual representation of, A, level; B, trend; and C, variability.



middle method, the more commonly employed trend analysis technique.

Variability (Figure 1C) refers to inconsistency or dissimilarity of data points in a series.[12] In SCD research, variability is controlled by first identifying the sources of variability and removing them. Implementation of the treatment is generally considered unwise until stability (low variability) is obtained during the baseline period. However, this is highly dependent upon the goal of the treatment. For example, if attendance at rehabilitation sessions (compliance) is the DV and the patient sporadically attends rehabilitation (eg, attends on Monday and Tuesday, but not again until Friday), stability may never be obtained. If the goal of the treatment is to stabilize (and improve) attendance, the treatment would be implemented despite (and even because of) a lack of stability in baseline behavior. Additionally, if the pattern of behavior during the baseline period indicates an increase in rate (and the goal of the intervention is to increase behavior), implementation of the treatment may not demonstrate a clear treatment effect, meaning it may be difficult to determine if the treatment caused an effect, or if the treatment had not been implemented, the effect would have been seen anyway.

Hrycaiko and Martin[13] suggest the use of a series of 5 guidelines to assist in establishing whether a treatment has had a clear and definitive effect. First, the final few data points of the baseline phase should be "reasonably stable"[13(p192)] or trending opposite to the predicted effects of the treatment. Second, replication of performance across all phases of similar conditions increases confidence in the effect of the treatment. Third, the number of overlapping data points between adjacent phases (ie, baseline and experimental) should be examined, with fewer overlapping points favoring an effective treatment. Fourth, the more immediately performance changes following a change in conditions (ie, introduction of the treatment), the more confidence the researcher would have in an effective treatment. Finally, large changes in performance suggest a more clear treatment effect. The use of these guidelines in conjunction with descriptive statistics assist the researcher in establishing the effectiveness of a treatment.[13]

As previously stated, the predominant mode of analyzing SCD research data is visual analysis. This differs from group-comparison designs, which use statistical analyses to make inferences about treatment effects for populations represented by a sample. The difference sheds light on a larger debate between clinical significance versus statistical significance. Experimental research results may show changes in data that are statistically significant but not clinically significant, or not statistically significant but clinically significant (ie, number of degrees of movement at the C2–C3 level during transfer of a spinal cord injured patient), or neither statistically nor clinically significant, or both statistically significant and clinically significant. Statistical significance involves "the amount of difference in the data series . . . whether the change is useful or desirable."[12(p451)] Clinical significance, however, focuses on the impact the treatment has on the subject him or herself. Clinical significance, or success of the treatment, has been defined as the expected outcome of the treatment.[3] With the emphasis in SCD being on clinically relevant, socially important behaviors, the seemingly arbitrary assignment of significance (ie, $P < .05$), typically seen in group-comparison designs, may hide nonstatistically significant results which may be clinically significant and therefore extremely valuable.[18] Since progress made in a therapeutic setting is readily observable, and may be clearly seen when graphed (see Vlaeyen et al[19]), the need for statistical analyses may be reduced.[13]

Advantages and Limitations

Advantages. One of the major benefits of using SCD compared to group-comparison design is the ability to change the treatment (independent variable) if unsuccessful.[5] In SCD,

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if the treatment is not producing the desired result, it may be adjusted and a new intervention phase initiated to determine the effect. This pattern of adjustment to identify an effective treatment is very similar to the therapeutic approach utilized in athletic training settings. The use of 1 specific treatment technique (eg, heel slides; Treatment A) to increase range of motion may not, after several attempts, be producing favorable results in the timeframe desired. The absence of favorable outcome with Treatment A may result in a different technique (eg, stationary bike rocks, Treatment B) being added to the treatment package. A comparison of these results would be possible with the alternating treatment design (see detailed description of this design in Design Options). The ability to adjust the treatment allows the researcher and clinicians to make a change and continue to evaluate the results, without waiting until the completion of the investigation.[5,12] Ultimately, this ability to alter the treatment to produce favorable outcomes has the potential to improve patient care through the identification of effective treatments.

The in-depth focus on 1 or a few subjects germane to SCD may be highly beneficial to a clinician treating an individual patient.[5] The intensive focus on the individual benefits both the patient and the clinician since a goal of applying a therapeutic intervention is to improve the condition of the patient. While SCD research is somewhat limited in its ability to generalize (see Limitations section), results indicating favorable outcomes with a small number of subjects may provide clinicians additional treatments to employ and opportunities to investigate the effectiveness of a specific treatment, should his or her patient be similar to the subject(s). Exposing all subjects to all levels of the treatment, at some point in the course of the investigation, further supports the use of SCD in athletic training. Less resistance to participation may be faced from subjects recruited for SCD research versus group-comparison design research due to the absence of a no-treatment control group.[13]

The nature of SCD to investigate the impact of a treatment on 1 or a few subjects may reduce costs, recruitment efforts, and time invested by the researcher and subjects.[13] Often, group-comparison design research requires intensive expenditures of financial and personal resources. Single-case design researchers may employ any of the various techniques discussed below to address clinically relevant topics with potentially less expenditure of resources.

Finally, the analysis of results from SCD research traditionally utilizes visual analysis. Through graphical presentations of the data, the impact of a treatment can often be easily seen, interpreted, and used more efficiently. The combination of easily interpreted results and individually oriented, clinically relevant treatments may provide clinicians a more efficient route to incorporating research evidence with their clinical expertise, in order to promote the adoption of EBP.[3]

Limitations. The most commonly stated limitation of SCD is the lack of external validity.[4,5,13] The key to generalizing SCD research lies with replication of the results with other patients, clinicians, researchers, settings, treatments, and behaviors. Obtaining similar results from multiple experimental situations contributes to the external validity of that intervention.[5,13] "Aspects of external validity are deliberately incorporated into certain single-case designs, (such as multiple baseline designs across individuals, behaviors, and settings)."[13(p192)] Replication and/or confirmatory group designs using an intervention that has been demonstrated to be effective, as stated above, are the key to establishing external validity of a treatment. However, SCD investigations that demonstrate a positive effect may provide an opportunity to advance an investigation to a higher level of scientific evidence and aid in the transition from unpublished clinical observations and prescientific knowledge development (ie, case study) to a scientific study.[3,20]

The intensive investigation of a single subject or a few subjects may also be problematic if the subject becomes ill, moves, withdraws from the therapy, or refuses to be treated.[5] However, subject attrition is a concern in any research involving human subjects regardless of the methodology employed. Developing an appropriate subject recruitment and retention plan prior to initiating an investigation, as in any research methodology, may reduce the impact of such events.

DESIGN OPTIONS

The general format of SCD research is very similar to the evaluation and rehabilitation process.[3] When a patient reports to an athletic trainer with a problem, the clinician evaluates, formulates an impression of the condition, and then initiates a treatment or intervention. As the patient returns for treatment, he or she is reevaluated, and progress is tracked (swelling reduction, pain reduction, increases in range of motion, etc). The clinician, based on the results of the evaluation, then decides to continue the current treatment or alter the treatment to seek different results.[3]

In a SCD study, a behavior is identified and measured over a period of time (baseline period).[3] An intervention (treatment) is applied, and changes in the behavior are tracked (intervention phase). Based on the results and the question(s) to be answered, the intervention may be removed or altered, and changes in behavior are once again examined.[3] The design options most appropriate for use in athletic training, depending upon the research question to be addressed, the data to be collected, and the subjects being studied, include: reversal (ABAB) design, multiple-baseline design, changing-criterion design, and alternating-treatment design. Regardless of the design option chosen, SCD relies on data from continuous assessment to describe the current level of performance and predict future performance if no intervention was applied. Data from the intervention phase(s) are then used to test these predictions.[4]

Reversal (ABAB) Design. Reversal or ABAB design is considered the most basic design within single-case research.[4] The general design (Figure 2) involves alternating between baseline conditions (no intervention present, or the A phase) and an intervention condition (B phase). Improvements in performance from baseline to the first intervention phase, followed by a reduction in performance when the intervention is removed, demonstrate the effects of the intervention. The baseline, as in any of the design options, serves to describe the current level of performance, as well as to predict future performance if no intervention was applied. The intervention phase follows the same pattern. However, it is the intervention phase which is used to test the prediction that performance

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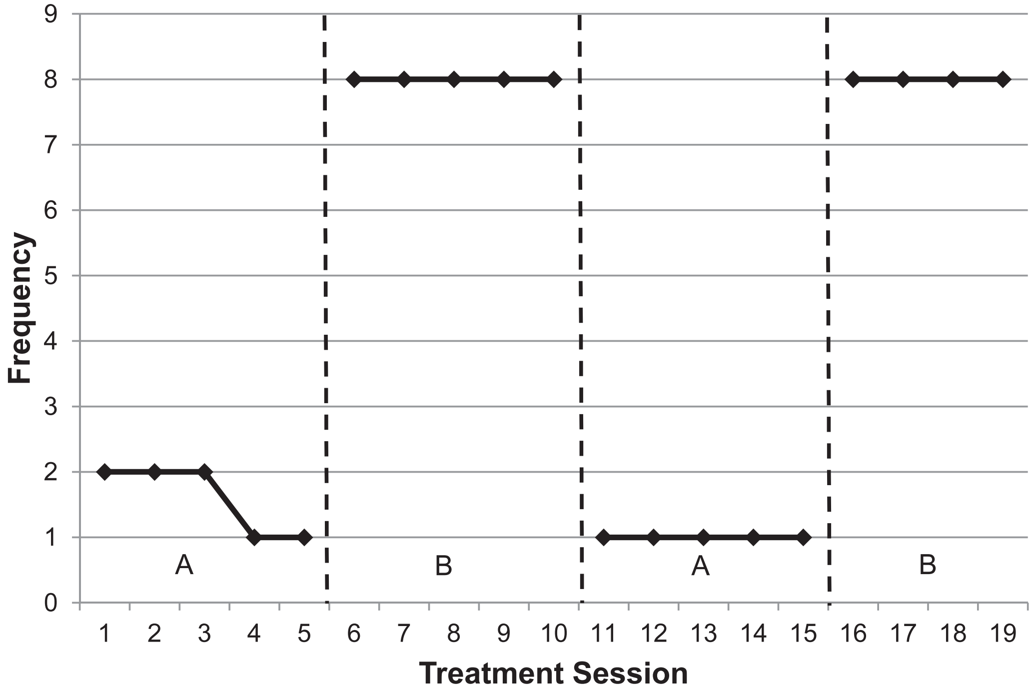
Figure 2. Visual representation of reversal (ABAB) design. A, Baseline phase. B, Intervention phase.



would remain the same if left unchanged, and therefore demonstrates the effect of the intervention. In order to improve the internal validity of the investigation, a second A phase is necessary to test the prediction of the previous phase (that is, if the conditions in the previous phase were left unchanged, would performance remain the same). Following the second A phase, the intervention is reintroduced, with the same purposes of describing, predicting, and testing previous phases. In other words, "the effect of an intervention is demonstrated by alternating intervention and baseline conditions in separate phases over time."[4(p143)] A variation of the reversal design is a multiple treatment reversal design (ABCBC) which uses the foundational baseline and intervention phases, but with an added intervention phase consisting of a novel intervention. A discussion of this specific variation can be found in Hrycaiko and Martin.[13] The logic of this design is seen in the alternation of the intervention phases to determine which intervention package produces the greatest change in behavior. However, limitations such as generalization to other behaviors, sequence of the treatments, and interactions of the treatments must be addressed in order to reduce threats to internal validity.[13]

Given ethical issues associated with removing a treatment shown to be effective,[4] and the lack of reversibility associated with improvements in a patient's condition (ie, increased range of motion due to treatment cannot be removed), the reversal design may not be appropriate for some behaviors in clinical athletic training settings (eg, increasing shoulder range of motion postsurgery). However, in certain educational settings, the implementation of a reinforcer (such as a reward or incentive, like positive feedback given for correct taping technique) followed by the subsequent removal of that reinforcer (ie, no feedback given) may be appropriate.

Multiple-Baseline Design. Multiple-baseline designs (MBD) utilize an extension of the baseline period of various lengths, depending on the research question, setting, and subjects.[4] Investigations employing MBD are a series of AB designs, with introduction of the intervention staggered over time systematically (Figure 3). The design may be used to explore the impact of a treatment across subjects, settings, or across behaviors. The length of the baseline phase may be predetermined, but is generally dependent upon the performance of behavior during the baseline phase. A minimum of 2 baselines are needed, with 3 or more to optimize the clarity of the effects. After extended baseline 1, the second subject is exposed to the treatment, and the impact of that treatment is evaluated. This pattern continues until all subjects have been exposed to the treatment. The effect of the intervention is seen in behavior that changes "when and only when the intervention is applied".[4] Staggering the introduction of the intervention strengthens the investigation through replication of the effects and through reductions in the influence of potential extraneous factors.[4]

Problems may develop when the behaviors being intervened are interdependent, when the intervention has an effect on some behaviors but not others (across-behaviors approach), and when ethical and practical considerations of withholding an effective intervention are seen.[4] Despite these potential problem areas, the popularity of MBD is in part due to the lack of a reversal phase.[4]

Changing-Criterion Designs. Changing-criterion design may also be applicable for use in athletic training. The effect of the treatment is demonstrated thorough gradual changes in behavior over the course of the investigation.[4] The key feature of this design is an incremental change that matches the performance criterion established across intervention phases. Visually, an effective treatment will be demonstrated through a steplike function (Figure 4). Following the baseline phase, a criterion level of behavior is established for the intervention phase. The criterion in subsequent intervention phases is established based on performance from the previous subphase, provided the behavior responds to the criterion. If

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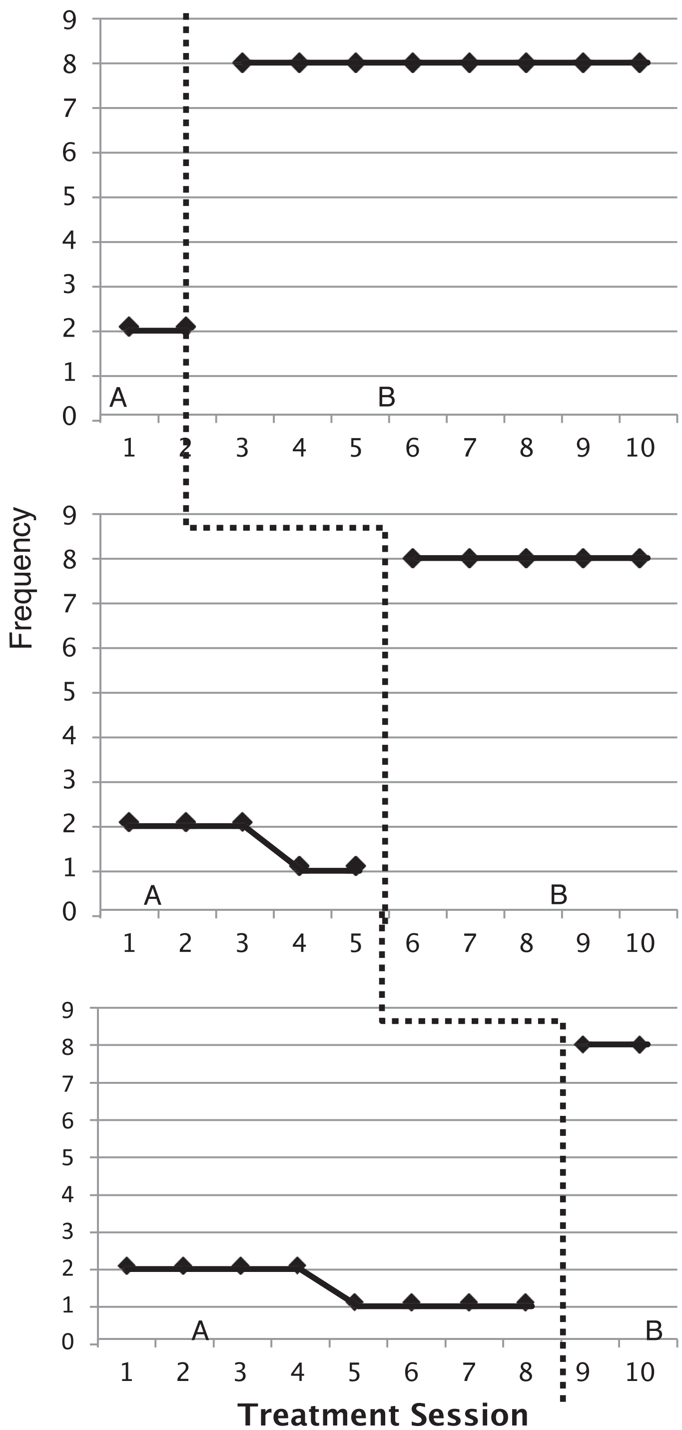
Figure 3. Visual representation of multiple-baseline design. A, Baseline phase. B, Intervention phase.



the performance corresponds closely to the various changes in the criterion, the intervention is considered effective.[4] Caution must be taken when establishing the criterion to ensure it is attainable by the patient and that changes in performance will be seen in a steplike manner. Traditionally, a minimum of 2 changes in criterion are necessary to demonstrate an effect, with 3 or more recommended.[4] Experimental control of the behavior may be further demonstrated through the introduction of a reversal phase, or a reduction in the criterion, to evaluate the corresponding response of the behavior.

Problems with changing-criterion design may develop if the performance does not follow shifts in the criterion due to a general improvement (or general influence) or because changes in the criterion are too small or too large.[4] As with multiple-baseline designs, changing-criterion designs do not require withdrawal of the treatment. The increase in performance across the investigation matches well with many rehabilitation situations, as the goal of the program is achieved gradually over time.[4]

Alternating-Treatment Design

The experience of the clinician and evidence from the literature may suggest multiple effective treatments. An alternating-treatment design (Figure 5) may be used to address questions related to which is most effective.[11] The distinguishing feature of this design is the "rapid alternation of 2 or more distinct treatments", while the effects on performance are measured.[11] "One treatment is typically applied during a session, and treatments are alternated across sessions."[11(p194)] Treatments may be alternated in daily sessions, separate sessions within the same day, or simultaneously within the same session.[11] The effect of the treatment is seen from 1 session to the next, with the subsequent data point providing prediction of future levels, verification of the prediction, and replication of previous effects[11]. "When the data paths for 2 treatments show no overlap with each other and either stable levels or opposing trends, a clear demonstration of experimental control has been made."[11(p189)] The effect of the different treatments is established by the distance between the respective data paths: the greater the difference, the greater the differential effect.[11]

Use of the alternating treatment design has several advantages, including not requiring an effective treatment to be withdrawn,[11] the ability to compare the effects of multiple treatments,[11,13] the absence of an extended baseline condition,[11,13] reduction in the effect of the sequence of the treatments,[11] and the opportunity to terminate less effective treatments earlier than other designs as the effects of the various treatments can be determined more quickly.[13]

Limitations to alternating-treatment designs, include generalization of behavior if the treatments are too similar, multiple-treatment interference (the effects observed when 1 treatment is applied may be different than when multiple treatments are alternated), and the need to identify treatments significantly different from each other.[11,13]

The use of alternating-treatment designs in athletic training may be beneficial when the clinician or researcher combines personal experience with evidence from research literature to investigate differences between effective treatments, thus engaging in EBP.

APPLICATION OF SINGLE-CASE DESIGN (SCD) IN ATHLETIC TRAINING

The emphasis on the development and implementation of EBP serves as a stimulus for the use of SCD in athletic training. A search of literature using common databases (Table 1) indicated few studies in athletic training that have used SCD. Many dissertations and theses have employed SCD

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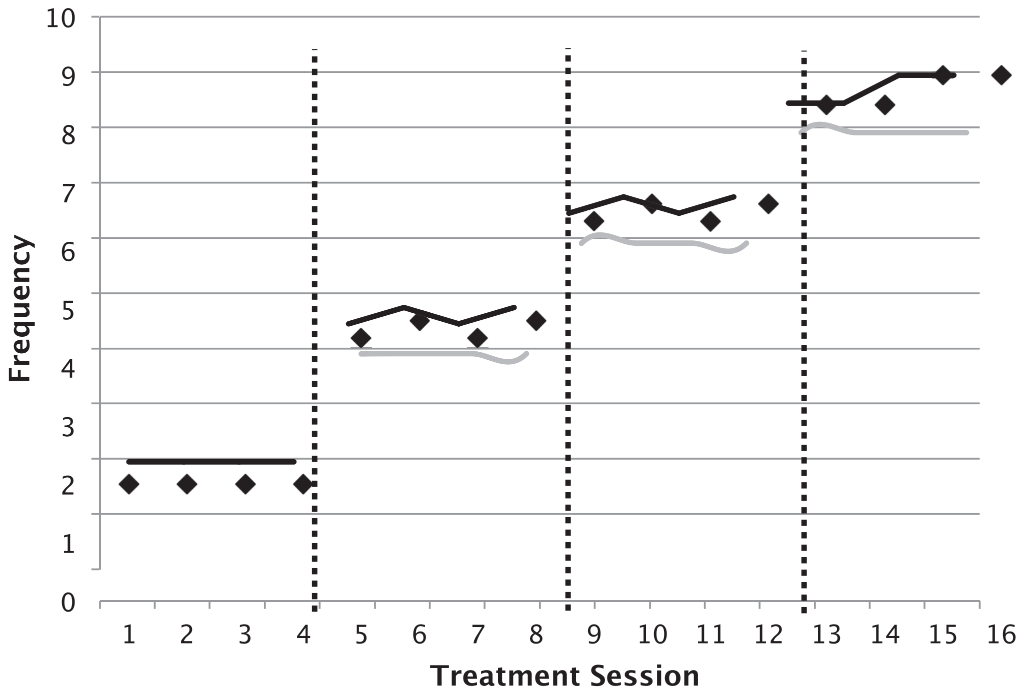
Figure 4. Visual representation of changing-criterion design. Solid horizontal line indicates criterion for phase. Gray lines indicate the target criterion for each phase. Black lines indicate the participant achieved a higher frequency of the target behavior than the target.



methodology; however, only 1 published study specific to athletic training[21] was found (Tables 1 and 2).

It is clear that the application of SCD in athletic training is a relatively blank canvas. However, SCD has been utilized to investigate a number of treatment interventions within athletic training settings. Ostendorf and Wolf[22] and Dawes et al[23] employed reversal designs to investigate the effect of exercise and rehabilitation on stroke patient hemiparesis. Maricar et al[24] used a multiple-treatment design to evaluate differences between 2 different treatment approaches on shoulder range of motion (ABCBC). Naoi,[14] Sheehy,[25] Wand et al,[26] and Wesch[27] adopted multiple-baseline designs to evaluate the effect of a mental skills training intervention on mood, pain, and adherence to rehabilitation;[14] the effectiveness of a coached exercise program on strength development;[25] senso-

Figure 5. Visual representation of alternating-treatment design. Top line represents Treatment A. Bottom line represents Treatment B.

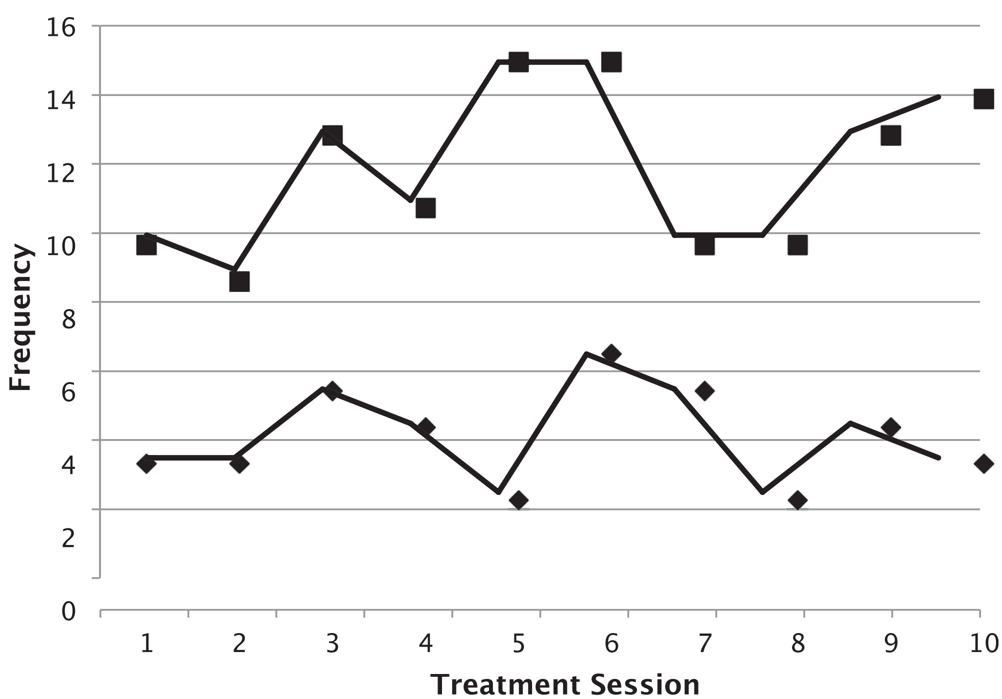


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Table 1. Use of Single-Case Design in Athletic Training and Allied Health

Database	Years	Number
CINAHL—no specifications	1993–2012	87
CINAHL—English, Allied Health	1993–2012	62
ProQuest Dissertations and Theses	1979–2012	927
ProQuest Dissertations and Theses—Allied Health	1979–2012	37
Google Scholar	1983–2012	1860
MEDLINE (PubMed)	1978–2012	107

rimotor training on chronic low back pain perceptions;[16] and the effect of imagery training on readiness for rehabilitation.[26] Finally, Shapiro[15] and Vlaeyan et al[19] employed multiple-treatment-reversal design to evaluate the effects of a mental skills training intervention on several psychological constructs as well as speed of recovery following injury and an intervention to address kinesiophobia in patients with chronic low back pain.

As an example of the applicability of SCD to athletic training research settings, Mattacola and Llyod[21] employed a multiple-baseline design across subjects to investigate the effect of a 6-week rehabilitation program consisting of manual strengthening and proprioception development on dynamic balance. In patients with a history of ankle instability, the results revealed a positive influence of strength and proprioception training on dynamic balance, as indicated by a decrease in the mean number of "touches" for all subjects in all testing conditions.

This investigation and those in other allied health professions highlight the potential for SCD research applications in athletic training. The client-centered, problem-driven, flexible process inherent to SCD makes it suitable for use both clinically and pedagogically. While group-comparison design investigations provide valuable information about the "average" individual, the information gained from SCD research yields equally valuable information about the individual patient(s) or student(s) who improve, deteriorate, or do not change. As these data accumulate in the literature, the evidence base expands and strengthens, resulting in improved outcomes. The focus on the treatment of an individual seen in SCD research mimics a similar focus in athletic training and addresses the hesitation to utilize a "cookbook" approach when applying therapeutic interventions. Additionally, applying SCD strategies in athletic training may provide clinicians and researchers an additional avenue to develop evidence regarding the effectiveness of treatments commonly utilized in the clinical setting. From a pedagogical perspective, SCD provides educators an opportunity to develop and evaluate

Table 2. Use of Single-Case Design in Athletic Training and Allied Health Professions

Study	Design Employed	Research Focus; Subject(s)
Ostendorf and Wolf[22]	ABA, reversal	Forced use of an affected upper extremity in a hemiplegic patient on functional behaviors; 50-year-old female stroke patient
Mattacola and Lloyd[21]	Multiple baseline across subjects	Ankle strengthening and proprioception training on dynamic balance; 16–19-year-old male boarding school athletes (3)
Dawes et al[23]	Reversal	High-intensity cycling on active elbow extension in a hemiplegic stroke patient; 24-year-old male stroke patient
Maricar, Shacklady, and McLoughlin[24]	Multiple treatment reversal	Exercise and mobilization on range of motion and pain in a patient with adhesive shoulder capsulitis; 54-year-old male with idiopathic adhesive capsulitis
Wand et al[16]	Multiple baseline across subjects	Sensorimotor training on perceptions of pain in patients with chronic low back pain; 29-year-old female waitress, 33-year-old school counselor, 55-year-old female nurse
Sheehy[25] (dissertation)	Multiple baseline across subjects	A nurse-coached exercise program for patients with tetraplegic spinal cord injuries on muscle strength; 16–65-year-old tetraplegic spinal cord injured patients (10)
Naoi[14] (dissertation)	Multiple baseline	Cognitive and relaxation intervention on injured athletes' mood, pain, optimism, and adherence to rehabilitation; college student-athletes (7)
Wesch[26] (dissertation)	Multiple baseline	Imagery training on self-efficacy and psychological readiness for rehabilitation following ankle fracture; 18–65-year-old (2 male, 4 female) with surgically repaired ankle fracture
Shapiro[15] (dissertation)	Multiple treatment reversal	A mental skills intervention on use, effectiveness, and satisfaction of mental skills straining, self-efficacy, attitude, speed of recovery; NCAA student-athletes (3 wrestling, 2 soccer, 1 cheerleading), postsurgical ankle, knee, and shoulder injuries

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Table 3. Additional Research Studies in Athletic Training Using Single-Case Design

Academic	Clinical
Use of incentives on execution of clinical skills (ie, taping and wrapping, special test performance)	Adherence to rehabilitation sessions, instructions Placebo effect of electric stimulation
Effect of various instructional technology on student learning/performance	Kinesiophobia Effect of manual therapy techniques on range of motion, pain
Effects of peer tutoring on academic performance, performance of clinical skills	Adherence to rehabilitation protocol Comparisons of various warmup methods on range of motion (ie, stationary bike vs moist heat pack)
Effect of clinical instruction approaches on athletic training student performance (ie, clinical skills, self-efficacy)	Impact of psychological interventions on performance of rehabilitation exercises, self-efficacy, adherence to rehabilitation Correct execution of rehabilitation exercises
The effect of a training program to increase clinical preceptor effectiveness	Correct execution of prophylactic strengthening exercises (ie, core strengthening, shoulder stabilization)

innovative educational practices, providing evidence of effective teaching strategies in athletic training education.

Employing SCD in athletic training may be limited by identifying dependent variables that are able to be operationally defined and measured objectively and reliably.[19] The association of SCD and ABA may have limited the use of SCD in other fields;[19] however, the results from searches of popular databases (Tables 1 and 2) indicate SCD research is being conducted in a variety of allied health fields, leaving the athletic training environment ripe for adoption. Finally, misunderstandings regarding the nature of SCD and a lack of coverage and exposure in research methods courses may be contributing to a general lack of familiarity with and use of SCD.[13,19] Calls for increased adoption of EBP in athletic training[27] may provide the impetus for increased instruction and use of SCD as an alternative approach to the development of evidence necessary to inform practice.

Despite these limitations, utilization of SCD may provide a supplementary approach to group-comparison designs traditionally employed in athletic training. Continual updates and changes in clinical and pedagogical techniques necessitate that clinicians, researchers, and educators identify and adopt evidence-based practices. Table 3 includes additional research studies in athletic training that could be investigated using SCD. Single-case design methodology may provide opportunities to investigate the multidisciplinary, multifactorial aspects of athletic training and athletic training education.

CONCLUSIONS

Single-case design research may be an alternative route to the development of evidence necessary to inform EBP. Single-case design provides athletic trainers a bridge to examine the clinical and academic environments to objectify clinical decision making and pedagogical practices and assists athletic trainers to develop as consumers and practitioners of scientific research. The variety of treatments or interventions that could be examined using SCD is limited only by a thorough understanding of the methodology. Decisions related to the choice of treatment, the effect of treatment, and the procedure(s) utilized to implement a treatment are made constantly in clinical settings. The ability to adjust an independent variable (the treatment) in response to an ineffective approach is likely to be accepted easily due to its resemblance with the therapeutic approach utilized in many athletic training settings. From a pedagogical viewpoint, athletic trainers constantly assess their effectiveness, making decisions about future directions, and adjusting their practices as necessary. Single-case design provides a methodology to objectify this decision-making process, allowing athletic trainers to engage in scholarship. Given limited financial resources and time constraints germane to athletic training settings, the limited resources generally needed to conduct SCD research lend further support to its use in athletic training and athletic training education research. Single-case design provides athletic trainers a tool to use their clinical expertise, develop evidence to inform their practices, and engage in EBP.

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