

'Psyching-Up' and Muscular Force Production

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Contents

Abstract	47
1. Strength	48
1.1 Supporting Research	48
1.2 Non-Supporting Research	49
1.3 Conclusions Regarding Strength	51
2. Muscular Endurance	51
2.1 Supporting Research	51
2.2 Non-Supporting Research	52
2.3 Conclusions Regarding Muscular Endurance	52
3. Power	52
4. Psych-Up Interval, Age and Competitive History	53
5. Reasons Why Psyching-Up Might Enhance Muscular Force Production	54
6. Future Research	56
7. Conclusions and Recommendations	57

Abstract

Psyching-up refers to self-directed cognitive strategies used immediately prior to or during skill execution that are designed to enhance performance. This review focuses on research that has investigated the effect of psyching-up on force production; specifically, strength, muscular endurance and power. Although firm conclusions are not possible, the research tentatively suggests that psyching-up may enhance performance during dynamic tasks requiring strength and/or muscular endurance. However, more research is required. Power has received scant empirical attention and there are not enough data to support any conclusions. Preparatory arousal appears to be the most effective strategy although other strategies like imagery, self-talk and attentional focus also have empirical support. The range of tasks that have been used to measure force production have been limited to movements such as handgrip, leg extension, bench press, sit-ups, press-ups, pull-ups, and the standing broad jump. Additionally, most studies have used undergraduate and/or untrained samples. Only a very small number of studies have examined well-trained individuals. Currently, no explanation for why psyching-up may influence force production has any substantive support. Although a small number of studies have examined moderating and mediating variables, few consistent patterns have emerged and knowledge in this area is somewhat restricted. Given the importance that many athletes place on their

mental preparation just prior to performance this is an area that warrants further examination. Research needs to examine a range of complex sport-specific tasks and use well-trained samples. Additionally, research needs to further examine why psyching-up may enhance force production.

Many strength athletes undertake some form of 'psyching-up' prior to performance, both in training and competition.^[1] Typical strategies include visualisation, cue words, attentional focus and preparatory arousal.^[1] These strategies are designed to increase physical and mental activation, narrow attention and build self-confidence.^[2] Athletes believe the result will be enhanced performance. This article will review research that has examined the effect of psyching-up on the generation of muscular force and will evaluate possible reasons why psyching-up may influence force production.

For this review, psyching-up refers to self-directed cognitive strategies used immediately prior to or during skill execution that are designed to enhance physical performance.^[2,3] Studies that investigated other types of interventions on force production such as music, external verbal encouragement and instructor-led guided imagery were not considered for this review. Initially, Sport Discus was used to identify relevant published literature. Keywords used during this search included strength, muscular endurance, power, psyching-up, psych-up, imagery, self-talk, arousal and mental preparation. The reference list of each article yielded by the Sport Discus search was then examined to identify additional references.

The major dependent variables measured in the research included strength, muscular endurance and power. For this article, the literature will be reviewed under these headings. Strength has been defined generally as the maximal force generated by a muscle or group of muscles at a specified speed.^[4,5] The strength section includes research that measured force production during a low number of repetitions such as a one-repetition maximum (RM). The muscular endurance section includes research that measured a high number of repetitions performed at a specified resistance level during a particular time period, such as the

number of sit-ups performed during 1 minute.^[4] Finally, the power section includes research that measured explosive strength, and power has been defined generally as the rate at which work can be performed under a given set of circumstances.^[4,6]

1. Strength

1.1 Supporting Research

Shelton and Mahoney^[1] published the first study that examined the effect of psyching-up on strength. Competitive weightlifters had their grip strength measured via a handgrip dynamometer across three trials. No intervention was used before the first trial but prior to the second trial participants engaged in a distraction task where they counted backwards in multiples of seven from 1000 (e.g. 1000, 993, . . .). Before the final trial participants were randomly allocated to one of two groups, either the experimental group or the control group. The experimental group were instructed to psych-up immediately prior to the handgrip task using their preferred mental preparation strategy, whilst the control group engaged in the distraction task for a second time. Results clearly showed that the experimental group significantly improved their performance while the control group had a non-significant decrease in performance. Since this initial investigation, several studies have also observed a positive effect of psyching-up on strength.^[7-15] The average difference between the amount of force produced during the psych-up conditions and the force produced during the control conditions has been 12% with a range of -1 to 35%. These figures represent the difference in force produced between intervention and control conditions, expressed as a percentage of the control condition. This crude estimate was based on the results of seven studies.^[1,8-11,14,15] Unfortunately, several studies did not report descriptive statistics so it is

difficult to accurately assess the magnitude of the psych-up effect.

In addition to Shelton and Mahoney's^[1] study, several other investigations have allowed participants to use their preferred psych-up strategy.^[11-13,15] The most common techniques participants have used include focused attention, preparatory arousal, imagery and self-efficacy statements. Additionally, many individuals have used a combination of techniques.^[1,11,12] The investigations that allowed individuals to select their own psych-up strategy have not directly compared the efficacy of the different methods. However, the majority of the research has compared the effectiveness of different psych-up strategies by prescribing the type of technique to be used.^[7-10,13,14,16] Preparatory arousal, imagery, focused attention, self-efficacy statements, self-talk and relaxation have been the strategies typically prescribed. Results suggest that preparatory arousal is the most effective technique.^[8,10,13,14] Additionally, evidence suggests that relaxation techniques lead to reduced strength performance.^[16-18]¹

The supporting research has used both within- and between-individual repeated measure designs and has also compared psych-up strategies with different control conditions.^[2] The most common has been the distraction control where participants have engaged in some non-related cognitive task, such as counting backwards or reading aloud. Three other control conditions used include non-intervention, quiet rest and a placebo condition where participants were given the expectation that their performance would improve but they did not psych-up. Of the supporting research, three studies^[1,10,15] have used trained or competitive weightlifters. Six studies,^[8,9,11,12,14] including two reported in one paper,^[8] used samples drawn from

undergraduate populations but did not specify the participants' training history. Two other studies^[7,13] used either participants undertaking weight training classes or sports participants but again did not detail the training history of the individuals. Eight studies,^[7-9,11-13,15] including two reported in one paper,^[8] used both males and females. Finally, three studies^[1,10,14] used males only. This breakdown of participants will be discussed at length when comparing the supporting research with the non-supporting research in the following subsection.

The type of task employed to measure strength has been largely limited to leg extension, handgrip and bench press exercise. The principle of specificity suggests that strength is defined in part by the nature of the task.^[2,5,19] Therefore, the findings from the existing research cannot be assumed to be applicable to tasks other than those investigated. Indeed, future research could examine the effect of psyching-up on a variety of other strength tasks, particularly those that are more complex or more applied to actual sporting performance. For example, squatting, javelin throwing and scrummaging in rugby union.

1.2 Non-Supporting Research

Despite the common finding that strength is improved via psyching-up, a number of studies have found no effect.^[2,16,18] For example, Brody et al.^[2] examined force production and electromyogram (EMG) activity in 15 well-trained males during an isometric biceps contraction with a 90° angle at the elbow. EMG activity and maximum force production did not differ across the psych-up or two distraction conditions. This is the only study that has measured strength with an isometric contraction and it is also the only study to specifically load the biceps muscles. Brody et al.^[2] suggested two possible reasons why the results differed from the supporting research. First, the supporting research has examined dynamic strength tasks while Brody et al.^[2] used an isometric contraction. During the dynamic tasks participants may have had the freedom to vary their posture and/or movement patterns

¹ The study by Pierce et al.^[17] does not strictly count as an examination of psyching-up because the interventions were not self-directed. The arousal intervention consisted of exposure to a video containing aggressive football footage while the relaxation intervention consisted of instructor-led progressive muscular relaxation. However, the study does provide evidence that undertaking relaxation prior to skill execution leads to reduced performance.

which then conferred a biomechanical advantage and/or facilitated the recruitment of additional muscle groups.^[2] Participants would not have had the same freedom to vary their posture and movement pattern in the isometric contraction examined by Brody et al.^[2] This suggests that psyching-up may enhance performance on dynamic strength tasks but does not lead to increased force production in a single muscle or muscle group. An individual may be able to lift more weight because more muscle groups are being involved in the movement, yet the individual muscles may not be producing more force. However, more research is required to test this hypothesis. Second, well-trained individuals were used in the study by Brody et al.^[2] while the majority of the supporting research has drawn from undergraduate populations with no clear description of the participants' training history, suggesting that the samples were untrained. Trained individuals are likely to have well-developed movement patterns and neural pathways that may not be readily modifiable by psyching-up, while untrained individuals may have less developed movement patterns and neural pathways that are modifiable.^[2] Additionally, the performance of untrained participants is likely to be characterised by greater variation compared with trained participants.^[2] Consequently, untrained participants may receive more benefit from psyching-up and therefore, the findings from the supporting research may not be generalisable to trained populations.^[2]

However, evidence is mixed regarding the relationship between isometric and dynamic strength tests.^[20,21] While the individuals in the study by Brody et al.^[2] were highly trained in a dynamic biceps curl movement it cannot be assumed that they were highly trained in an isometric biceps contraction. Therefore, the participants may not have had well-developed neural pathways for an isometric contraction. Additionally, three studies from the supporting research have used trained volunteers.^[1,10,15] Brody et al.^[2] was unable to determine the reasons for differences in their findings compared with the supporting research. However,

Brody et al.^[2] highlight the important need for future research to consider the training history of the participants and various types of strength, such as isometric and dynamic strength.

Another example of a study that found psyching-up had no effect on strength was that by Tenenbaum et al.^[18] Positive self-talk (PS) and relaxation-visualisation autogenic training (RVA) were compared with a non-intervention control group. This study measured both peak force and peak power during an isokinetic bilateral knee extension exercise. Novices with no prior resistance training experience were used and the two intervention groups were given four sessions of instruction in the use of the psychological technique they had been allocated. While all three groups improved their peak force production pre- to post-test, the control group had a significantly greater improvement than both the PS and RVA groups. Additionally, the PS group had a greater improvement than the RVA group. The peak power results are discussed under the power heading.

The results regarding the reduced performance from the RVA group is supported by other research and suggests that relaxation is not an effective means of psyching-up.^[16,17] However, the lack of superior strength over the control group by the PS group differs from other research that has used an isokinetic knee extension exercise.^[8,9,12,14] This includes a study that found PS was associated with superior strength.^[9] The major difference between Tenenbaum et al.^[18] and other research was the four sessions of instruction that were given to the intervention groups. Tenenbaum and colleagues^[18] suggested that performance might have been hindered because the novice participants had to divide their attention across both the strength task and the psych-up strategy as a result of the four instruction sessions. Indeed, research does suggest that if the attentional demands of a task exceed the attentional capacity of the athlete then performance may suffer.^[22]

Similar results were observed in a study that compared fear-, anger- and relaxation-based imagery on handgrip strength.^[16] Non-intervention pre-

test and post-test trials were also included. The results revealed that relaxation-based imagery led to lower strength scores than all the other conditions, and the pre-test strength scores were higher than the scores during fear-based imagery and the post-test trials. All other comparisons were nonsignificant. When combined with other research, these results suggest that relaxation-based strategies lead to reduced performance.^[17,18]

The finding that fear- and anger-based imagery were not associated with superior strength contradicts other research that has found imagery to improve performance when used as a psych-up strategy.^[1,7,8] A difference between the study by Murphy et al.^[16] and other research was the focus of the imagery technique. During the Murphy et al.^[16] study, participants were asked to imagine a scene in which they felt angry, afraid or relaxed. The images created by the participants may not have been related to the handgrip task. Previous research has generally used images that are related to the strength task being performed.^[1,7,8] This difference in results suggests that psyching-up may lead to increased strength if the strategy helps the athlete to focus on the task. However, fatigue is a possible alternative explanation for the results observed in Murphy et al.^[16] There was a significant decrease in performance between the pre- and post-test trials. It is not clear how much rest was allowed between trials. Consequently, participants may have experienced fatigue and this may have overshadowed any psych-up effect.

1.3 Conclusions Regarding Strength

Although the majority of the research generally supports the hypothesis that psyching-up enhances strength, firm conclusions are not possible because a number of issues require further research. Research needs to explore the relationship psyching-up has with various types of strength such as isometric, isokinetic and isotonic contractions. This research also needs to include a larger variety of movements including sport-specific compound strength tasks. Additionally, more studies examining well-trained samples are required to assess

whether these types of individuals might benefit from psyching-up. Finally, future investigations could examine the interactions between psychological instruction, strategy familiarity, training history, attention and strategies that are specific and non-specific to the task.

2. Muscular Endurance

2.1 Supporting Research

While the majority of research has focused on strength there has been some attention, albeit limited, to both muscular endurance and power.^[9,18,23-25] While the research that has examined muscular endurance has indicated that performance improves with psyching-up, there is considerable need for more research.^[9,23-25]

The average difference in performance between psych-up interventions and control conditions is 11% with a range of -1 to 29%.^[9,23-25] These figures were calculated as previously described for strength from four studies.^[9,23-25] As an example of the research that has examined muscular endurance, Caudill and Weinberg^[23] compared the effects of various psych-up strategies and various psych-up intervals on the number of repetitions performed to failure during the bench press. Participants consisted of 30 male and 30 female students enrolled in a weight training class. Preparatory arousal, focused attention, imagery and quiet rest were the psych-up strategies investigated. Participants were required to psych-up for 15, 30 or 60 seconds prior to the bench press task in a two (gender) by three (psych-up interval) by four (psych-up technique) repeated measures design. All three psych-up strategies led to greater performance than the quiet rest condition. However, there were no differences among the three psych-up interventions or across the three time periods, neither were there any interactions.

The supporting research has used both within- and between-individual repeated measure designs. The control conditions have consisted of non-intervention, quiet rest and cognitive distraction. However, all samples were drawn from student

populations and there were no indications that participants were experienced or well-trained. The tasks used by the supporting research to measure muscular endurance have consisted of sit-ups, press-ups, pull-ups, and the bench press.^[23-25] The research has typically compared the effectiveness of various psych-up interventions by directing volunteers to use a particular method, although Weinberg et al.^[25] also allowed volunteers to select their own strategy as one of the psych-up conditions that they investigated. The typical strategies that have been compared include imagery, self-talk, preparatory arousal and attentional focus. There is no evidence supporting any strategy as being more effective than another, although one study did suggest that task-relevant imagery led to superior muscular endurance over task-irrelevant imagery.^[24]

2.2 Non-Supporting Research

One study has produced results that did not support the efficacy of psyching-up on muscular endurance.^[9] Instructional and motivational self-talk were compared with a non-intervention control group using the number of sit-ups performed in 3 minutes as the measure of muscular endurance. Participants began with a baseline trial and then were allocated to the instructional self-talk, motivational self-talk or non-intervention control group. The second trial took place 5 days after the baseline trial with the final trial occurring after a second 5-day period. All three groups improved their performance across the trials with no significant differences separating the groups. It is possible that a training effect may have occurred and this may have overshadowed any psych-up effect. Alternatively, during a post-experimental manipulation check, 53.4% of the control group reported that they had been thinking about something specific when they were performing, although the content of their thoughts were not described. These participants may have been thinking about the test and could have spontaneously been using self-talk.

2.3 Conclusions Regarding Muscular Endurance

The research to date suggests that the use of task-relevant psych-up strategies may lead to improved muscular endurance. However, given the small number of studies conducted, more research is required to substantiate this conclusion. A limited range of tasks has been examined and future research could investigate the impact of psyching-up on applied sporting movements that require muscular endurance, such as groundwork in judo, mauling in rugby union, and gymnastics. Additionally, as undergraduate populations have been used as volunteers it is uncertain whether the results are applicable to those that are well-trained. Hence, future investigations need to examine participants with an extensive training history.

3. Power

Very little research has examined the effect of psyching-up on muscular power and the results from these few studies have been conflicting.^[18,25] For example, Tenenbaum et al.^[18] compared a non-intervention control group with a positive self-talk group and a relaxation-visualisation autogenic-trained group. A pre-post test design was used with the task being a bilateral knee extension movement performed at 180°/sec. The control group had a higher peak power output during the post-test than the two intervention groups. However, all three groups improved by 9% from pre- to post-test. As mentioned in the strength section, this investigation also examined peak force, used novices and gave the intervention groups four sessions of training in the relevant psych-up strategy. It was suggested that performance might have been hindered because the novice participants had to divide their attention between both the task and the psych-up strategy as a result of the four sessions of instruction.^[18] Indeed, as mentioned in section 1.2, if the attentional demands of a task exceed the attentional capacity of the athlete then performance may suffer.^[22]

The other study to examine power used the standing broad jump as its performance measure.^[25] Participants consisted of 24 male students enrolled in a weight training class. The psych-up strategies used in this study were imagery, preparatory arousal, 'free choice', and a distraction control condition. While there were no differences among the psychological interventions, all three yielded significantly greater performances than the control condition by 2%.

Clearly, there are not enough data to guide practice with respect to muscular power until more research is completed. This may be a particularly important area of research. For many sports the development of strength alone is insufficient to enhance performance; often athletes need to produce strength in a short time period.^[6] Hence, power may be more important to athletic performance in many sports than absolute strength.^[6] Although related, researchers need to be aware of the differences between strength and power.^[6] They also need to establish which type of force production is to be measured and consider its application to sporting performance.^[6]

4. Psych-Up Interval, Age and Competitive History

Two studies have examined the effect of varying the length of the psych-up interval on performance and both found no differences among the time periods.^[12,23] The first has already been discussed in detail under the muscular endurance heading and the performance measure was the number of bench press repetitions performed to failure.^[23] While the psych-up strategies led to a greater number of repetitions, the various time intervals of 15, 30 and 60 seconds did not influence muscular endurance. Four time intervals were used in a similar study that measured isokinetic leg strength.^[12] These were: (i) a 15 second interval; (ii) a 30 second interval; (iii) a self-initiated interval where participants took as long as they believed was necessary; and (iv) a 'yoked' condition where participants were paired with individuals in the self-initiated condition. That is, participants

were asked to psych-up for the same amount of time as their 'partner' had taken during the self-initiated condition. Using a non-intervention control condition and a 'free-choice' psych-up strategy, results suggested that there were no differences between the various time intervals. However, results also suggested that psyching-up led to greater strength. Taken together these two studies provide evidence that the time taken to mentally prepare may not influence the relationship between psyching-up and force production.^[12,23]

The interaction between age and psyching-up was the focus of a study that measured handgrip strength.^[7] Preparatory arousal, imagery and distraction were the intervention conditions. Sixty individuals were divided into four groups; older males (mean age [M] = 59.93 years, SD = 2.57), older females (M = 60.33 years, SD = 2.31), younger males (M = 22.14 years, SD = 2.81) and younger females (M = 20.96 years, SD = 2.56). There were no interactions between psyching-up and age but imagery produced greater strength scores than the distraction condition and younger participants were stronger than older participants. However, older participants reported higher levels of somatic anxiety. They also felt they were able to count backwards and perform imagery more than the younger participants were.

On a related theme, another study stratified individuals according to their level of competitive experience.^[13] Individuals who had not played competitive sport or who had just participated in recreational exercise were classed as having low levels of experience. Those who had participated in high school or recreational sport and who perhaps had played some college intramural or recreational sport were classified as having moderate levels. Those participants who were deemed to be highly experienced included collegiate or semi-professional athletes and/or those with a significant competitive history in a number of sports at high school. The effects of preparatory arousal, self-selected psych-up, attention-placebo and cognitive distraction on handgrip strength were investigated. The use of prescribed preparatory arousal

led to greater performance in moderately experienced participants only, while the use of self-generated strategies led to higher strength scores in participants with high levels of competitive sporting experience. Whelan et al.^[13] suggested that mental preparation strategies could be learned through experience or could be quickly trained after moderate amounts of competitive sporting experience. This second suggestion may appear to contradict Tenenbaum et al.^[18] whose findings indicated that training individuals led to a decrease in performance. However, these two studies examined different populations. The participants in the Tenenbaum et al.^[18] study were novices in resistance training, whereas the participants in Whelan et al.'s^[13] study who improved their strength scores during prescribed preparatory arousal had at least a moderate amount of experience in competitive sport.

The above studies have begun to examine the effect of moderating variables like age, competitive history and intervention interval on the mental preparation-force production relationship.^[7,12,13,23] However, the paucity of data means that it is difficult to draw any conclusions. Instead, it is clear that research needs to further examine the possible interactions between psyching-up and other variables on force production. An understanding of why psyching-up may affect force production would help guide the selection of appropriate moderating and mediating variables for this research. This article will now evaluate possible explanations that have been given for the mental preparation-force production relationship.

5. Reasons Why Psyching-Up Might Enhance Muscular Force Production

Changes in psychological states have been postulated as the major reason why psych-up strategies may enhance force production.^[3,26] Specifically, increased force production may result from increased arousal, enhanced self-efficacy and focused attention.^[2,3,26] Indeed, research has attempted to examine whether improvements in force production are associated with changes in

such variables.^[2,7,11-14,16,23-25] However, an inconsistent pattern of results has emerged and changes in psychological states have largely not been in the expected directions. For example, Lee^[24] found that task-relevant imagery led to a greater number of sit-ups performed in 30 seconds compared with task-irrelevant imagery. However, higher vigour and lower fatigue were associated with irrelevant imagery rather than relevant imagery as would be expected. Additionally, while Brody et al.^[2] found no differences in performance on an isometric biceps flexion exercise, participants perceived that they had higher levels of arousal and attention when they psyched-up. In contrast, Weinberg et al.^[11] observed that higher perceived effort was associated with leg strength during psyching-up. Taken together, the results from these investigations do not support the conjecture that psyching-up enhances force production via changes in psychological states.^[3,13,26]

However, a major limitation with this research could be the heavy reliance on data that is self-reported.^[2,7,11,12,14,16,23-25] Participants may not be capable of accurately reporting their higher order cognitive processes.^[23,26,27] Indeed, it is possible that the questionnaire data collected was influenced by participants' beliefs about the extent to which arousal, attention and self-efficacy should have changed with psyching-up rather than solely reflecting relevant introspection.^[23,27] It would be advantageous for research to examine psychological states in a variety of ways rather than solely relying on questionnaire data. However, for psychological variables like self-efficacy and attention, self-report data will most likely continue to be collected because other methods are not readily available.^[3]

Some research has attempted to assess arousal by measuring physiological variables.^[13,17,28] However, results have still been equivocal. Whelan et al.^[13] found that heart rate was not related to increased strength or psyching up. Related research that has used instructor-led guided interventions rather than self-directed strategies, has also provided mixed results. Pierce et al.^[17] found

that preparatory arousal led to higher strength performance compared with relaxation and control for a 1RM bench press while relaxation led to reduced strength performance for a 3RM bench press. Consistent with these performance measures, heart rate was lower during relaxation and systolic blood pressure was higher during preparatory arousal. In contrast, Perkins et al.^[28] found that heart rate and autonomic nervous system activity did not mediate the relationship between handgrip strength and guided imagery.

Although more research is needed, the measurement of physiological variables has not helped explain if a change in arousal is the reason why psyching-up may lead to greater force production. While this line of inquiry warrants further attention, valid measures need to be established. Arousal is a multidimensional construct that consists of various psychological and physiological factors.^[3,26] Consequently, multiple measures may be needed to accurately assess if arousal is a mechanism underlying the possible psych-up and force production relationship.^[3,26] As an illustration, heart rate may not be a suitable sole measure of increased arousal when examining force production. While an increase in sympathetic nervous system activity increases heart rate, heart rate can also increase from reduced parasympathetic nerve activity.^[28,29]

From a neurophysiological perspective, Brody et al.^[2] suggested that psyching-up might lead to changes in motor unit recruitment within the muscle. Specifically, it was hypothesised that there could be an increase in motor unit activation in the agonist muscle and a decrease in motor unit activation in the antagonist muscle. However, there were no differences in EMG activity in either the biceps or triceps muscles across various psych-up conditions during an isometric contraction performed by experienced male weight-trainers. As previously mentioned, this investigation also found that psyching-up had no effect on maximal force production. The use of a constrained isometric contraction was the major difference between the study by Brody et al.^[2] and other research,

which has used dynamic strength tasks. During dynamic strength tasks, individuals may have the freedom to vary their posture and/or movement pattern to secure a biomechanical advantage and/or facilitate the recruitment of additional muscle groups.^[2] This may not be possible during a constrained isometric contraction. Psyching-up may not lead to an increase in force production within a single muscle or muscle group but perhaps in dynamic strength tasks psyching-up may allow individuals to enhance their performance. However, this hypothesis needs to be tested empirically.

Currently, no explanation for why psyching-up may enhance force production has any substantive support. This is largely due to the lack of empirical attention. Future research needs to continue investigating why psyching-up may improve force production. The existing literature suggests that psychological, physiological and mechanical variables may all play a role. Hence the selection of appropriate variables needs to be based on the factors that influence the display of force.

The force produced during a voluntary contraction of skeletal muscle is determined by a series of factors beginning with input from the higher motor centres and terminating with the energy-dependent interaction of actin and myosin.^[30-32] These factors may be classified as central, peripheral and mechanical influences.^[32] Central components include motor unit recruitment, synchronisation and firing rate.^[33,34] Peripheral factors include processes intrinsic to the muscle like the excitation of the muscle membrane, release of calcium, sarcomere length and myosin adenosine triphosphatase activity.^[33,34] Finally, mechanical factors include the length of muscle, velocity of contraction and the physical arrangement of muscle fibres.^[33]

The increase in force production resulting from psyching-up may be determined by changes in the factors mentioned above. It is likely that psyching-up affects the CNS. The cerebral cortex is the first and highest level of muscular contraction control.^[35] Self-directed cognitive strategies or

psyching-up will likely occur in the cerebral cortex. Therefore, psyching-up may stimulate changes in CNS activity resulting in adjustments in motor unit recruitment, synchronisation and/or firing rate. Similarly, changes in the CNS may modify sympathetic nervous system activity, which may result in alterations in peripheral factors like muscle contractility.^[36] These changes at the level of the muscle could occur in the primary muscles responsible for the movement, the antagonist muscles and/or any additional muscles that could contribute to the movement.^[2] These hypothesised changes could underlie the increase in force production that results from psyching-up. However, research is required to investigate these possibilities. To investigate such mechanisms, future research needs to continue to measure psychological states such as attention, self-efficacy and arousal. Additional variables that could be measured include the electrical activity of the muscle using EMG, electrical brain activity using an electroencephalograph and muscle activation via electrical muscle stimulation. Finally, it is possible that the interactions amongst these variables mediate the relationship.^[26] Hence future research needs to examine these interactions, possibly through the use of path analysis.^[26]

6. Future Research

It seems surprising that the mental preparation-force production relationship has received limited empirical attention given the value that athletes place on their mental preparation immediately prior to competition. Although the reviewed research has contributed much to the understanding of psyching-up on force production there is still much to be learnt. This section will outline general directions for future research. First, future research reports need to be complete and precise. For example, previous research has not always been clear about what type of force production was measured. Various types of force production can be quantified such as strength, endurance and power.^[2,37] Additionally, the type of task being performed can influence the assessment of force production.^[5,19]

Future research needs to clearly specify the type of force production being measured. A further example is the inclusion of descriptive statistics with the results. Many investigations have only included the outcomes from inferential statistical tests. The addition of descriptive statistics is important because they help readers to evaluate findings.^[38] A lack of precise description makes it difficult to appraise or replicate a study. Brody et al.^[2] is an example of a study that has been precise and complete in its description.

The relationship between psyching-up and both muscular endurance and power needs further examination. Both of these variables have received scarce empirical attention, particularly power. The results from the research that has examined strength cannot be assumed to generalise to muscular endurance or power. In many sports the development of strength is not as critical to performance as the ability to either produce force quickly (i.e. power) or to maintain force over time (i.e. endurance).^[6] Therefore, it is possible that research investigating power and endurance may be more applicable for some sports than research that has examined strength.

Along a similar line, a restricted range of tasks has been examined in previous research. These have included leg extension, handgrip, sit-ups, bench press, press-ups, pull-ups, and the standing broad jump. Future research could examine a larger variety of tasks. The principle of specificity suggests that strength is defined in part by the nature of the task.^[2,5,19] Therefore, results from previous investigations may not generalise to all movements. Many sports require compound movements that involve the entire body. However, these types of tasks have largely not been investigated. Research that uses sport-specific movements may be more applicable to athletes.

The majority of the research conducted so far has used samples drawn from undergraduate and/or untrained populations.^[2] It is not clear whether the results observed in these groups can be generalised to well-trained populations.^[2] Yet it would seem that the group most interested in this

research would be sports participants. Future research needs to investigate the effect of psyching-up in a larger variety of samples.

Sports performance often requires more than just strength. Many skills require other facets, such as timing and technique. Murphy and Woolfolk^[39] found that relaxation led to increased putting performance in golf while preparatory arousal did not. This finding differs from the force-production literature that has suggested that preparatory arousal leads to greater performance while relaxation leads to reduced performance. However, many sports require a combination of skill, timing and force production like gymnastics, cricket and wrestling. Future research could examine the effect of psyching-up on sport-specific movements that require high levels of both strength and skill, such as scrummaging in rugby union, pace bowling in cricket, and floor exercises in gymnastics.

Future research could also further examine moderating variables that may influence the mental preparation-force production relationship. Based on existing research, variables that warrant investigation include technique instruction, competitive sporting experience, mental preparation experience, resistance training history, task-relevant and task-irrelevant psych-up strategies. Additionally, future research needs to further investigate the mediating variables that underlie the mental preparation-force production relationship. Examining mediating variables will contribute to the understanding of why psyching-up may enhance force production. Possible variables worthy of consideration include the electrical activity of the muscle or contractility, electrical brain activity and muscle stimulation. A conceptual understanding of why force production may be enhanced via psyching-up along with knowledge of the factors that influence the relationship, may allow recommendations given to athletes to be based on empirical data.

7. Conclusions and Recommendations

Based on the research that has been reviewed in this article, firm conclusions are not possible. In-

stead, it is tentatively suggested that psyching-up may enhance performance during dynamic tasks that require strength and/or muscular endurance. However, it is not clear whether all individuals may benefit from psyching-up or if just untrained individuals benefit. While preparatory arousal seems to be the most effective strategy, a number of others also have empirical support. These strategies include imagery, attentional focus and self-efficacy. However, it is likely that any technique that leads to appropriate activation and attentional states will enhance performance.^[3]

Psyching-up refers to self-directed cognitive strategies designed to enhance performance. This article has reviewed the research investigating the impact that psyching-up has on muscular strength, endurance and power. While evidence generally suggests that psyching-up enhances strength and muscular endurance, more research is needed to investigate the applicability of these initial studies beyond the limited range of tasks and participants that have been examined. Additionally, very little research has examined power and no conclusions are possible. Finally, research needs to investigate the possible reasons why psyching-up may be effective. Given the importance that many athletes place on mental preparation immediately prior to performance it is clear that empirical attention in this area is warranted.

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