SCIENTIFIC MAGAZINE

13

The official journal of the European Weightlifting Federation. Year 5 Number 13 - May - August 2019

calzetti & mariucci editori

SCIENTIFIC MAGAZINE

PUBLISHER
Calzetti & Mariucci Editori
By Roberto Calzetti Editore srl
Via del Sottopasso 7 – Loc. Ferriera
06089 Torgiano (PG) Italy
Phone / Fax +39 075 5997310 – 5990017
E-mail: info@calzetti-mariucci.it
Web: www.calzetti-mariucci.it

PRINTED BY
Studio Stampa New Age
Strada Cardio 58 – Zona industriale Galazzano
47899 Repubblica di San Marino

studiostampa

CORRESPONDENCE
EWF – Viale Tiziano 70 Roma
E-mail: presidente@federpesistica.it
E-mail: secretariat@ewfed.com
E-mail: info@calzetti-mariucci.it

COMMUNICATION AND WEB AREA
· Colin Buckley
· Hasan Akkus

IMAGES & ARTWORKS BY
· EWF · FIPE · NSCA · ELEIKO

EDITORIAL MISSION STATEMENT

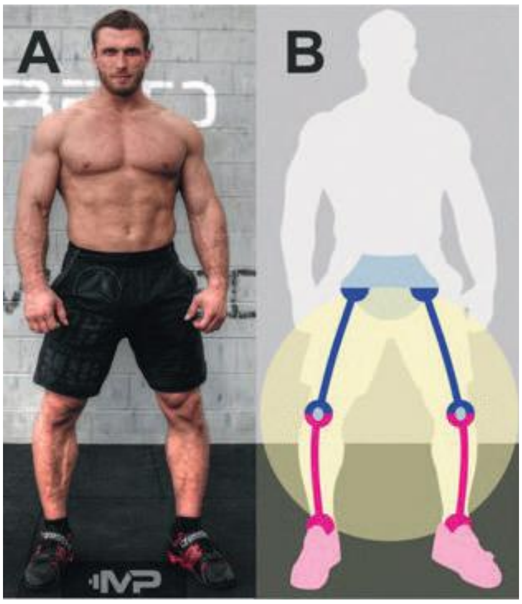
The editorial mission of the EWF – Scientific Magazine is to advance the knowledge of human movement based on the assumption that it is firstly, by any standard, the expression of muscular strength and secondly, a way of life and an ethical approach entrusted to professionals who not only are highly qualified, but also have full knowledge of the scientific facts, as well as being specifically competent. From its first issue, EWF – Scientific Magazine, has set itself the ambitious goal of bridging the gaps between the scientific laboratory and the operator on the field, enhancing both the practical experience of the coaches and the results of applied research. Consequently, the editorial rule will be a constant reference to practice and the publication of recommendations on how to apply the results of research to the practice of movement and sport.

The official journal of the European Weightlifting Federation - N° 13 / May-August 2019

SUMMARY

"...the highest retro-patellar compressive forces and stresses (at knee joint) can be seen at 90°".

Hartman, 2013



58

The morphological structure of Dimitrij Vjaceslavovic Klokov (born in 1983, 105 kg body weight, 183 cm height), former weight lifter (169 kg maximum lift in the Snatch, 232 kg maximum lift in the Clean), participated in the 2008 Beijing Olympics, retired from competitions in 2015...

EDITORIAL

Coaching in this day and age. Reflections on an increasingly complex profession.

N° 13 / May-August 2019

Coaching has always been complex, coaching has always required great professional skills, knowledge in different fields and, in particular, critical thinking. Because yes, coaching is substantially a critical mindset, the ability to explain phenomena which often are not measurable but, nevertheless, greatly influence performance.

Today, however, coaches are required to go even further. They need to possess authentic managerial skills that go beyond the mere application of the method and beyond the evaluation of the same. The world of today's athletes has totally changed in the space of just a few years. Interests have changed, the way in which we choose a sport has changed, as has the way in which we live a sport. The way that groups created within sports interact with each other has changed. The way of communication between the various figures in the sporting world: coaches, athletes, management, family, public. In fact, everything has changed in communication - from method and timing, to contents and interests.
The organisation of the world of sport has also undergone change. Many of the rules that regulate the world of sport have been altered. There is much more sedentariness and an intensification of physical inefficiency. There is an increasing number of disuse pathologies, and lifestyles that are not befitting to the protagonists of sport.

In addition to all this change, coaches find themselves sharing their role with a whole series of parallel figures who interact with the athlete, the trainer, the managers and with the federations, or clubs. The big clubs in particular. We could call it a whole new world. A sort of puzzle that introduces competences, conflicts, different points of view, different approaches that should then merge into one reasoned solution. This also applies to personal trainers who work in fitness centres or on a one to one basis. All very interesting, fascinating even.

How does a coach prepare for all this? What training is provided in a country that should devote time to these aspects and implement the best projects on these aspects? The answer is that there can be no answer. The world of training in this field is too complicated and too afflicted. To begin with, however, we should establish a univocal, resolute definition, recognised by specific legislation that begins with stating who a coach is and what characteristics he/she must have. Lastly, what minimal training he/she must possess and, who certifies all the above.

We have entered a perfect Tower of Babel. In Italy anyone can do training in this area. No experience is required, and neither competence nor quality is assessed. Only the institutional sports sector has a minimum number of regulations for the training of coaches or adherence to the European Qualification Framework, designed for national federations. This has partly solved the problem, in other words, it has been established in quantitative terms what must be done, how many hours for example, to dedicate to one subject as opposed to another. However, this has nothing to do with controlling the quality of the training and the trainers.

A real dilemma, to which we must add the training of those who fail to follow even these minimum rules and go crazy in a market without rules. Since there is therefore no real regulation in this regard, today anyone can become a coach or personal trainer or physical trainer in a couple of weekends. And the European community? It has never actually raised the question, it has never given an appropriate and definitive answer, and often it even seems ignorant of the problem. Again, for example, many training institutions, in the free market, omit or make misleading advertising claims about the legal value of the qualification. They never explain where a qualification can be used and its real application.

And if it is true that a lot has changed in the world of sports and recreation, then perhaps it is time that the international Federations or the IOC decide what is the path one must follow to enter into the world of sport, and demand that every professional figure have tread this path and have a minimum standard of qualifications and quality.

Antonio Urso
EWF President

EFFECTS OF BODY DISSATIS-FACTION

TRAIT ANXIETY ON SELF-ESTEEM IN YOUNG WEIGHTLIFTERS

BY KHIZER HAYAT


10
15
15
15

The official journal of the European Weightlifting Federation

INTRODUCTION

A strong body with muscularity is the dream of human beings. It is in the instinct of human to be strong and attract the people and symbol of bravery. Where a strong and muscular body inspire the other it also positively effects psychologically, develop confidence and strengthen the self-esteem. If we look back in the history we found many precedents of Zeus and Samson who had strong body and admired by the kings of that era. Iranian Rustum is also a precedent of strong body muscles in the history. A beautifully developed body can be gained with vigorous resistance exercises and constant hard work recognized attractive personality.

During present times the will to gain a strong body with strong muscles is living in the society and for this purpose to gain it, people are moving to the fitness gyms for weight training and other resistance exercises. Men and women are strongly willing to gain an attracted body for an impressive personality. Beside this their psychological benefits are additionally boosting their self-esteem and helping against the anxiety.

Olympic weight lifting is popular individual sport and all the sportsmen engaged or active in this sport are well built and have good body image due to the direct involvement of resistance deals (Kraemer & Fleck, 2005). Most research on male self-perception concentrated on body weight and strength, in any case, late confirmation proposes that male self-perception is intricate and multidimensional, and errors between the real and the perfect can apply to different parts of appearance (Tylka and Wood-Barcalow, 2015).

One investigation found that men were disappointed with a few parts of their bodies they needed to be more slender, taller and stronger. In any case self-perception disappointment regularly brings about negative self-perception which may likewise be factors contributing the broad research enthusiasm for this region (Przezdziecki et al., 2013). It is in this way fundamental to consider the significance of appearance when mental associates or outcomes of body disappointment are analyzed.

There are many components can impact Olympic weightlifting execution. All in all, these can be partitioned into here and now factors, for example, recuperation status, hydration status, dietary and late rest quality and span (Löffler et al., 2007). Long haul variables can be subdivided into mental zones and all the more regularly looked into physical territories, for example, age, anthropometrics, muscle fiber compose, and quality. Self-perception, uneasiness and confidence are the components which impact the execution of weightlifters. This investigation will help in evaluating the above last three factors help in upgrading the execution of weightlifters.

BODY DISSATISFACTION

Before going in to detail in our examination paper some data about the self-perception is important to clarify. For the most part self-perception alludes to how an individual sees their own particular body, and particularly how appealing they feel themselves to be. Generally men and ladies are worried about their self-perception. It doesn't imply that what you look like in, its allude excellence and manly and solid human body. In sports and particularly in weightlifting self-perception alludes to the well fabricated and solid muscles in an angular shape body (Galli, Petrie, Reel, Chatterton, & Baghurst, 2014).

A man with a constructive self-perception has a genuine and clear view of their body shape and appearance that other individuals would concur with. This is known as the body fulfillment. The individual is glad about the way they look, and they acknowledge and like their body and their appearance help in building the certainty and confidence. They know that what they look like isn't their identity. They are pleased with the way they look and feel sure about their body. A sound way of life, with an adjusted eating routine and exercise, can add to a positive self-perception (Seligman & Csikszentmihalyi, 2014). Some portion of having a positive self-perception is simply the capacity to isolate how we esteem ourselves from what we look like. Individuals who understand that self-esteem isn't connected to appearance tend to like what they look like. In weightlifting self-perception is firmly identified with body fulfillment (Webb, Butler-Ajibade, & Robinson, 2014).

Self-perception impact on confidence and many examinations have surveyed the connections between fundamental anthropometric estimations and Olympic weightlifting capacity (Lippi et al., 2014). Body weight and muscle versus fat ratio are generally perceived as key drivers, with higher body weight and lower muscle to fat ratio being related with predominant capacity (LI et al., 2014). While couple of effective male Olympic weightlifters are taller than 6'0" and couple of fruitful female

Olympic weightlifters are taller than 5'9", body tallness does not give off an impression of being a key issue that can separate between officially fruitful competitors. What's more, despite the fact that the ownership of more prominent bulk or size differentiates Olympic weightlifters from ordinary control subjects, it doesn't seem to separate well amongst world class and sub-first class competitors (Bona et al., 2012).

An investigation found that ladies' mentality to their self-perception has a tendency to stay stable all through their life expectancy, in spite of the fact that the significance of shape, weight, and appearance diminish with age. Negative self-perception mean body disappointment which prompts nervousness pre and amid rivalry which causes low confidence and execution decay (Tremblay et al., 2016).

ANXIETY

Then again, tension is by definition a disagreeable sensation. The accompanying meaning of tension: 'a negative passionate state with sentiments of anxiety, stress and worry related with enactment or excitement of the body (Weinberg and Gould, 1995). We would thus be able to consider tension an unpalatable condition of high excitement (Tenenbaum and Eklund, 2007).

Then again nervousness is by definition an upsetting sensation. Weinberg and Gould in (1995) have offered the accompanying meaning of uneasiness: 'a negative enthusiastic state with sentiments of anxiety, stress and fear related with actuation or excitement of the body. We would thus be able to consider tension a disagreeable condition of high excitement.

Soma is a Greek word which signify "body". When we are on edge we encounter the physiological changes related with high excitement, including expanded heart rate and circulatory strain, 'butterflies' in the stomach, speedier breathing and flushed face. These impacts are comparable (however not indistinguishable) to the physiological impacts of fervor and outrage. We call the experience of physiological changes related with tension substantial nervousness.

In this psychological stage competitors feel that they have stomach issue or they feel urinary pack is loaded with pee in substantial Anxiety. In the wake of start of rivalry physical uneasiness decay strongly (Collin and Otero, 2015).

Subjective tension alludes to the restless musings that go with physical nervousness. On edge thinking includes stresses, self-questions and pictures of losing and mortification. Various investigations have inspected how subjective and physical uneasiness change before a brandishing occasion. (Jones, Swain, and Hardy, 1993) took after forty-nine olympic style events competitors, measuring both the recurrence and force of their psychological and physical tension on four events (two days, one day, two hours and thirty minutes) preceding a critical rivalry. They found that both intellectual and substantial tension expanded before the occasion, the most emotional increment being in the recurrence of restless reasoning instantly before rivalry. When rivalry starts subjective uneasiness change depends how the occasion is going (Smith, Norris, and Hogg, 2002).

The term pressure has a more extensive significance than uneasiness. Stress is the procedure whereby an individual sees a danger and reacts with a progression of mental and physiological changes, including expanded excitement and the experience of tension. We tend to encounter pressure when we meet requests that are hard to meet, however which convey genuine outcomes in the event that we neglect to meet them. In the event that pressure is long haul, or constant, it can make genuine damage both physical and psychological well-being. While it is very typical – and as we might see very valuable to encounter some uneasiness before contending, competitors ought not feel continually restless and consider themselves to be confronting inconceivable chances (Tenenbaum and Eklund, 2007).

SELF ESTEEM

Keeping in mind the end goal to comprehend confidence we have to see how analysts characterize self-idea, for instance, portrays the self-idea as 'a composite picture of what we think we are, what we want to accomplish, what we think others consider us and what we might want to be.

Low confidence allude to a man don't have faith in his qualities and not fit to confront the circumstance fearlessly. Low confidence in weightlifting gravely harm the execution amid training and rivalry too. Individuals with low confidence convey inside them an objecting guardian who is brutally disparaging of their disappointments, and enroll just fleeting joys when they succeed. Such individuals are well-suited to be unduly touchy to disappointment and to dismissal, to have low resistance for dissatisfaction, to set aside a long opportunity to recoup following frustrations, and to have a negative perspective of life.

High confidence alludes to putting stock in our self and having the ideal level of certainty that we can con-

front the circumstance with every one of the instruments required. Weightlifting with high regard is dependably help in improving the execution amid preparing and rivalry too. A solid body additionally help in high confidence. Individuals with high confidence, essentially, convey with them a cherishing guardian who is glad for their triumphs and tolerant of their disappointments (Harter, 2015). Such individuals have a tendency to have a hopeful view about existence, and to have the capacity to endure outside worry without winding up unnecessarily on edge. Albeit equipped for being baffled and discouraged by particular encounters, individuals with high confidence recoup rapidly.

For the most part specialists are consistently concurred over this point activities can help a man to be more sure about their quality and dexterity, and it can add to keeping up a solid weight and body measure. It can likewise lessen nervousness and dejection. In any case, individuals practice for various reasons. In an examination analysts found that individuals who practice for useful reasons, keeping in mind the end goal to be fit, have a tendency to have a more positive self-perception. The individuals who exercise to enhance their appearance feel positive about their bodies. Analysts and games researcher recommend stressing the useful advantages of activity and de-underscoring the intentions that identified with outside appearances, to enable individuals to cultivate a more positive self-perception (Tremblay et al., 2016) . Olympic weightlifting is additionally great to enhance the self-perception and help in having the solid angular body with solid muscles.

METHODS

These include population, instruments (questionnaire), procedures, data collection, and data analyses. The research follows quantitative research methods because the data for this study is collected in numeric form.

Research Objective

Following are the research objectives of the study:

1) To measure the effect of body dissatisfaction on self-esteem of young weightlifters.
2) To quantify the relationship of body dissatisfaction on anxiety of young weightlifters of Pakistan.
3) To study the effect of anxiety on self-esteem of young weightlifters.
4) To measure the effect of body dissatisfaction and anxiety on self-esteem of young weightlifters of Pakistan

Hypothesis

Following are the research hypotheses of the study:

H1) There is a positive relationship between body dissatisfaction and self-esteem.

H2) There is a negative relationship between anxiety and self-esteem.

H3) Higher the body weight of the weightlifters, higher will be the self-esteem

H4) There is a significant impact of body dissatisfaction and trait anxiety on self esteem

Of young weightlifters.

Sample

In this research the data is collected from 124 respondents out of 180 weightlifters by using simple random sampling technique followed by random number generator. The following formula will be used for calculation of the required sample size. (Yamane, 1967).

n = N/1+Ne2

n= 180/1 + 180 (0.05 0.05)

n= 180/1 + 180 (0.0025)

n= 180/1.45

n= 124

Operational Definitions

Body Dissatisfaction

Body Dissatisfaction was assessed through the scale of body shape poll (BSQ-34) by Cooper, Taylor, Cooper and Fairburn (1986). This thirty four thing scale measures mental worry about body shape. Inquiries identified with respondent's state in the course of recent weeks are replied on six point Likert scale (1=never to 6=always). Higher scores show more noteworthy body weight concerned and body weight disappointment.

State Trait Anxiety

State trait anxiety will be measured through the scale of state trait anxiety inventory (Spielberger, 2010). This 40 items self-report measure assesses both how he or she generally feels (Trait Anxiety). The items were rated on a four – points Likert scale (1=not to 4=very much) higher score indicate greater trait anxiety.

Self Esteem

Self-esteem of the weightlifters was assessed by using Rosenberg Self Esteem scale (RSES) by (Rosenberg & Court, 1979). This ten items scale measures global self-esteem, which is defined as a person's overall evaluation of his or her worthiness as a human being. The items were rated on a four point Liker Scale (1= strongly disagree to 4 =strongly agree) Higher score on the scale indicates higher self-esteem.

PROCEDURE

The test booklet comprised of three questionnaire along with demographic sheet. 124 weightlifters selected through random sampling technique were approached individually. The respondents were approached individually and assured that the information they will provide will be kept confidential and it will be used for academic purpose only.

They were requested to read each statement in every questionnaire carefully and to ask if there is any ambiguity. They were encouraged to respond honestly as their best knowledge. They are also told that the results of the research will be shared with them. All the filled questionnaire will be coded and complied in SPSS software. Data analyzed through the use of SPSS version 20.0. For statistical purpose, frequency distribution higher test like Regression ANOVA analysis will be used according to the needs of the data.

CONCLUSION

The detail of the experiment is shown through graphics below:

SCALE	FREQUENCY	PERCENTAGE	VALID PERCENT	CUMULATIVE PERCENT
Male	109	87.9	87.9	87.9
Female	15	12.1	12.1	100
Total	124	100	100	

TABLE 1: Gender Detail

AGE OF RESPONDENT	TOTAL NUMBERS	PERCENTAGE
12 – 19	36	29
20 – 27	69	55.6
28 – 35	8	6.6
36 – 43	6	4.8
44 – 52	5	4
Total	124	100

TABLE 2: Age of participants (N=124)

BODY WEIGHT OF RESPONDENT	TOTAL NUMBERS	PERCENTAGE
40 – 59	30	24.2
60 – 79	42	33.9
80 – 99	36	29
100 – 119	14	11.3
120 – 139	2	1.6
Total	124	100

TABLE 3: Body Weight of Participants (N=124)

EXPERIENCE OF RESPONDENT	TOTAL NUMBERS	PERCENTAGE
1 – 6	88	71
7 – 12	23	18.6
13 – 18	5	4
19 – 24	3	2.4
25 – 30	5	4
Total	124	100

TABLE 4: Experience of Participants (N=124)

SCALE	FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
Club	12	9.7	9.7	9.7
District	48	38.7	38.7	48.4
Provincial	17	13.7	13.7	62.1
National	37	29.8	29.8	91.9
International	10	8.1	8.1	100
Total	124	100	100	

TABLE 5: Participants Level of Sports

MODEL 1	SUM OF SQUARE	DF	MEAN SQUARE	F	SIG
Regression	72.248	2	36.124	3.336	.039B
Residual	1310.139	121	10.828		
Total	1382.387	123			

TABLE 6: ANOVA

MODEL 1	SUM OF SQUARE	DF	MEAN SQUARE	F	SIG
Regression	.722	2	.361	3.336	.039[B]
Residual	13.101	121	.108		
Total	13.824	123			

TABLE 7: ANOVA[a]

For many years researchers found male body satisfaction was focused on body weight and muscularity, henceforward, recent research suggests that male body satisfaction is complexed and multidimensional. In some studies it was found that men always willing to be thinner, taller and muscular ones and their effects on self-esteem. Many predictors of positive appearance of self-esteem found that effects of body dissatisfaction and anxiety on self-esteem of young weightlifters of Pakistan, have found it appealing to encourage them towards their goals and negative appearance of self-esteem creates a vice versa impact on the enthusiast.

In this research study we examined the relationship between body dissatisfaction and anxiety on self-esteem of young weightlifters of Pakistan, and study proved that strong relationship between body dissatisfaction and anxiety on self esteem.

R squared model established in this research is used to check the relationship whether it is positive or negative. Positive relation mean that if independent value is increasing the dependent will decrease. R values always lies between -1 to 1. If the R value is greater than 0 the relation is positive and if the value of R is less than 0 the relation is negative.

Regression analysis 1 of our research proved that bodysum and anxietysum has a positive relation on selfsum because R is 0.229.

Regression analysis 2 of our research proved that body dissatisfaction and anxiety have positive effects on self-esteem because R is 0.229.

To make our research more authentic we conducted ANOVA analysis. In this analysis we established a f (Fitted) model which is used to plot the values nearer to each other on the graph. The fitted value must be greater than Sig. if the f value is greater than Sig. then there will be a strong relationship between independent and dependent variables.

In this case our fitted model will be considered as significant model because the fitted model predict 95% accuracy in results.

In regression analysis 1 f is 3.336 and Sig. is 0.039 which shows our fitted model is accepted and it predicts a significant value.

In regression analysis 2 f is 3.336 and Sig. is 0.039 which shows our fitted model is accepted and it predicts a significant value.

In this research we are close to predict significant results for this we established T model which is also called T test. If the T test is greater than Sig. so the values are near to its mean the test reflect that relationship is strong between dependent and independent variables.

In regression analysis 1 T is 1.957 and Sig. is 0.53 which clarify that values are near to its mean and relationship is strong between bodysum, anxietysum and selfsum.

In regression analysis 2 T is 1.957 and Sig. is 0.53 which clarify that values are near to its mean and relationship is strong between body dissatisfaction, anxiety and self-esteem.

LIMITATION

This research was conducted on young weightlifters of Pakistan and research is limited to body dissatisfaction, anxiety and self-esteem there are other factors through which we can predict effects on self-esteem such as body weight dissatisfaction, height dissatisfaction, body mass index and importance of participation in competition.

Further research can be conducted to inspect whether our discoveries can be sum up to various games. It would likewise be important to explore previously mentioned factors utilizing a model of comparative multifaceted nature utilized as a part of this investigation.

REFERENCES

1. Baker, A. B., & Tang, Y. Q. (2010). Aging performance for masters records in athletics, swimming, rowing, cycling, triathlon, and weightlifting. Experimental aging research, 36(4), 453-477.
2. Baker, D. G., & Newton, R. U. (2008). Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. The Journal of Strength & Conditioning Research, 22(1), 153-158.
3. Cooper, P. J., Taylor, M. J., Cooper, Z., & Fairbum, C. G. (1987). The development and validation of the Body Shape Questionnaire. International Journal of eating disorders, 6(4), 485-494.
4. Erikson, E. H., & Erikson, J. M. (1998). The life cycle completed (extended version): WW Norton & Company.
5. Ernst, A. (2016). 7-WEEKS OF YOGA TRAINING AND ITS EFFECTS ON FLEXIBILITY, RATE OF FORCE DEVELOPMENT, AND JUMP HEIGHT IN OLYMPIC WEIGHTLIFTERS.
6. Galli, N., Petrie, T. A., Reel, J. J., Chatterton, J. M., & Baghurst, T. M. (2014). Assessing the validity of the Weight Pressures in Sport Scale for Male Athletes. Psychology of Men & Masculinity, 15(2), 170.
7. Gamble, P. (2006). Periodization of training for team sports athletes. Strength and conditioning journal, 28(5), 56.
8. Gill, D., Williams, L., & Reifsteck, E. (2017). Psychological dynamics of sport and exercise: Human Kinetics.
9. Klomek, A. B., Marrocco, F., Kleinman, M., Schonfeld, I. S., & Gould, M. S. (2007). Bullying, depression, and suicidality in adolescents. Journal of the American Academy of Child & Adolescent Psychiatry, 46(1), 40-49.
10. Kraemer, W. J., & Fleck, S. J. (2005). Strength training for young athletes: Human Kinetics.
11. Moreno, K., Soliz, J., Cortez, S., Antelo, S., Burgos, G., Galetovic, M., . . . Irusta, G. (2016). Olympians from the Latin American countries overviewed in the final chapter. Women and Sport in Latin America, 239.
12. Nieuwoudt, J. E., Zhou, S., Coutts, R. A., & Booker, R. (2015). Symptoms of muscle dysmorphia, body dysmorphic disorder, and eating disorders in a nonclinical population of adult male weightlifters in australia. The Journal of Strength & Conditioning Research, 29(5), 1406-1414.
13. Radcliffe, J. N., Comfort, P., & Fawcett, T. (2015). Psychological strategies included by strength and conditioning coaches in applied strength and conditioning. The Journal of Strength & Conditioning Research, 29(9), 2641-2654.
14. Rosenberg, M., & Court, D. (1979). Regulatory sequences involved in the promotion and termination of RNA transcription. Annual review of genetics, 13(1), 319-353.
15. Seligman, M., & Csikszentmihalyi, M. (2014). Positive psychology: An introduction (pp. 279-298). Netherlands: Springer.
16. Spielberger, C. D. (2010). State-Trait anger expression inventory. The Corsini Encyclopedia of Psychology, 1-1.
17. Szabo, A. S. (2012). Some questions of biomechanical character in weightlifting. Sports Specific and Practical Aspects, 9(1), 59-64.
18. Tenney, E. R., Logg, J. M., & Moore, D. A. (2015). (Too) optimistic about optimism: The belief that optimism improves performance. Journal of personality and social psychology, 108(3), 377.
19. Teo, S., Newton, M. J., Newton, R. U., Dempsey, A. R., & Fairchild, T. J. (2016). Comparing the effectiveness of a short-term vertical jump versus weightlifting program on athletic power development. Journal of strength and conditioning research/ National Strength & Conditioning Association.
20. Tod, D., & Edwards, C. (2015). Relationships among muscle dysmorphia characteristics, body image quality of life, and coping in males. Journal of Science and Medicine in Sport, 18(5), 585-589.
21. Webb, J. B., Butler-Ajibade, P., & Robinson, S. A. (2014). Considering an affect regulation framework for examining the association between body dissatisfaction and positive body image in Black older adolescent females: Does body mass index matter? Body image, 11(4), 426-437.
22. Yamane, T. (1967). Statistics: An introductory analysis.

REALANALYZER HD

A REAL-TIME BARBELL TRACKING SOFTWARE FOR WEIGHTLIFTING

BY I. SANDAU, H. JENTSCH, M. BUNK


15
TRAINING
KG
15
TRAINING
KG

INTRODUCTION

In elite sport the biomechanical analysis of competition and training exercises provides fundamental information on the technical and physical requirements, from which the training process can be improved to enhance competition performance (5). Competition performance is measured by an output of the sports movement (the athlete itself or the sporting equipment). For weightlifting, the performance is measured in kilograms. An athlete will win the competition in a respective weight category if he or she lifts the highest barbell weight. For lifting high weights, the athlete has to accelerate the barbell, jump under the barbell und finally catch the barbell on straight arms above the head. The athlete stays in contact with the barbell over the entire movement until he drops the bar after the referee's vote. During the lifting motion the lifter and the barbell act like a common system – the barbell-lifter-system (4,15). Because of this specific characteristic, much of the athlete´s movement will be reflected in the barbell movement.

This circumstance can be used in biomechanical analyses of weightlifting. It´s much easier and less time consuming to analyze the barbell than the body movement. This is why most studies of weightlifting focus on barbell movement. Of course, not all aspects of the lifter's movement can be rated directly by the barbell motion. But especially for coaches the barbell provides a lot of easy-to-handle information (6). In fact, with the help of computer science much deeper analyses of the barbell movement are possible. Kipp, Giordanelli, Geiser (3), who predicted net joint moments with an artificial neural network from barbell trajectory only, recently showed how much information is "hidden" in the barbell movement.

In weightlifting, analyzing the barbell is a very old approach to rate the lifting technique. Textbooks from the 1960s (14) already gave detailed barbell trajectories and implications for a good technique. In Germany, research on weightlifting has a long history. Back in the mid-1960s, research on weightlifting started in the German Democratic Republic at the Research Institute for Physical Culture and Sports (FKS) in Leipzig to support the national weightlifting team. The early barbell tracking approaches were based on cinematographic recordings (8). At that time, barbell trajectory was tracked manually from the analog film on a punch card from which further computer-based (digital) calculations were done. Afterwards the calculated 2D coordinates were transferred onto millimetre paper to draw the trajectory manually. It took about 2 weeks to receive a barbell trajectory and biomechanical data for an analysis of 10 athletes from a competition.

At this time, a parameter-based feedback training was inconceivable. The only way to obtain instant information on weightlifting performance in the training process was via a linear position transducer that was developed at the FKS (7). With this device, it was possible to measure the maximal barbell velocity. In the mid-1980s, development of digital techniques made it possible to make digital video recordings instead of analogue cinematographic recordings. Researchers from the weightlifting research group at the FKS started in 1986 with first attempts of video recordings at the European championships. With a digital video, the manual barbell tracking via computer was much faster, but it still took several minutes to get the results of an analysis. Even with digital video recordings, a parameter-based feedback in training was impossible. First steps with immediate feedback on barbell trajectory were possible with the Israeli V-scope system (1,13). Unfortunately, this system had three major drawbacks: 1) no synchronous video recordings of the trajectory and the time-series data, 2) a marker attachment on the barbell (not suitable for competitions; in training the marker often was damaged when dropping the barbell), 3) the V-scope system was susceptible to too much sunlight (disruption of infrared signal) or additional noise (disruption of ultrasound signal) while lifting. Because of this, in 2000 Holger Jentsch and Dr. Jürgen Lippmann from the Institute for Applied Training Science (IAT, the former FKS) developed the custom built software Weightlifting Analyzer with an automatic barbell tracking algorithm for video recordings (2).

Since then it has become possible to receive an analysis of the barbell within approximately 30 seconds after the lift was finished. Although the Weightlifting Analyzer was able to present the video and the barbell analysis very quickly, there was always a wish for immediate data on barbell motion after the lift. With ongoing development in computer science and video tracking algorithms, in 2008 the researcher at the IAT built a new software with a real-time tracking of the barbell, the Realanalyzer.

With this software, the analysis of the barbell takes approximately 1 second. The researcher and the coach immediately receive a biomechanical analysis of the barbell to give feedback to the athlete. The video recordings of the Realanalyzer at that time were based on the DV format (standard definition, 720 x 576 pixels, interlaced). The DV format and the associated techniques (Camcorder, Fire-Wire connection to computer) are outdated today. Further development to HD video format was therefore necessary.

In this paper, we introduce the brand new barbell tracking software Realanalyzer HD for weightlifting that was developed at the IAT in Leipzig. We present some technical details of how to track the barbell on HD video and provide information regarding software evaluation, measured parameters and data interpretation.

VIDEO CAPTURING AND REAL-TIME TRACKING

Video capturing

Although HD video recording is not difficult today, since every smart phone is able to record HD videos, the challenge was to find a way to stream the live HD video signal in real time with access to every single frame via USB from a camcorder to the computer. The solution adopted for this is a commercial video converter (manufactured by AverMedia) that receives input from a camcorder via HDMI and gives an H.264 compressed output stream via USB.

Because of the specific requirements, a camcorder with video-output per HDMI of 1280x720 pixels at 50 frames per second (progressive) is necessary. The live stream is then captured in the *Realanalyzer* HD software.

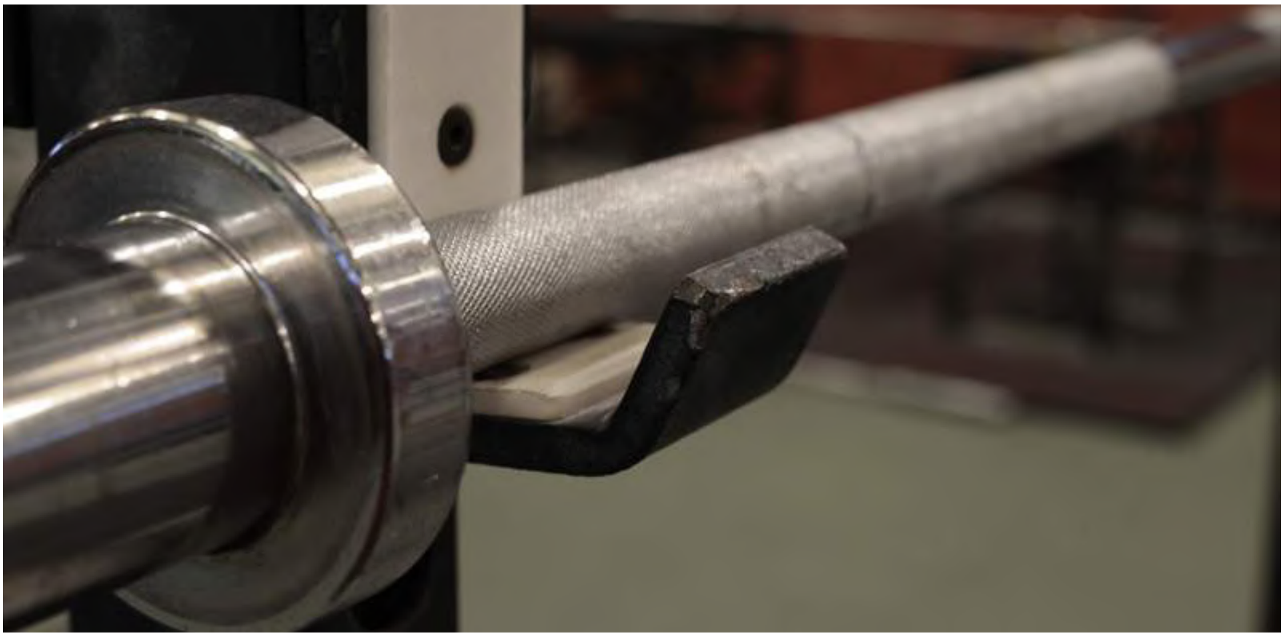
Real-time tracking

In the next step the barbell tracking on the live video stream is realized by a template-matching algorithm. To start the tracking, the user only needs to click on the live video and define which template to track - for weightlifting the plates of the barbell. The software automatically identifies the beginning of the lift and starts tracking. After finishing the lift, the software automatically stops tracking again. The stored raw pixel coordinates (horizontal [x], and vertical [y] direction) from the tracking are smoothed with a cubic spline function. The smoothed pixel data represents the traveled distances of the barbell. To obtain velocity and acceleration the 1st and 2nd derivatives have to be calculated. This is done via the cubic spline function. After this step, additional discrete parameters are calculated from time-series data of distance (trajectory) (x, y), velocity (y) and acceleration (y). Finally, the pixel-coordinates are converted to real distances in metres via 2D image calibration. The barbell plates are used for this purpose. The diameter of 45 cm is a standardized size for all big plates in weightlifting and so an easy scale of reality is obtainable. The entire process of data preparation (smoothing, calculating) is done in less than 1 second after the lift. The researcher or coach immediately gets the biomechanical analysis of the barbell (fig 1.). Furthermore, with the Realanalyzer HD a post hoc tracking of the barbell from a recorded mp4 clip is also possible. After the lift, all data and the video can be stored in an embedded database (fig. 2).

FIGURE 1:
MAIN WINDOW FOR THE MEASUREMENT: 1) LIVE VIDEO PREVIEW WITH TEMPLATE DEFINITION FOR TRACKING (UPPER LEFT), 2) ATTEMPT SETTINGS FOR DATABASE (EXERCISE, NAME, LOAD, SET, REPS), 3) VIDEO PLAYBACK AFTER TRACKING WITH 4) FREE ADJUSTABLE DIAGRAMS AND TABLES WITH BIOMECHANICAL DATA

FIGURE 2:
DATABASE OF REALANALYZER WITH OVERVIEW OF BIOMECHANICAL PARAMETERS (BACKGROUND) AND LOADED ATTEMPT WITH VIDEO, DIAGRAMS AND TABLE (FOREGROUND)

N° 13 / May-August 2019



Setup and system requirements
A biomechanical analysis of the barbell movement with the Realanalyzer HD is very simple. The entire system consists of four parts:

1) camcorder on a tripod,
2) video-converter,
3) USB and HDMI cable,
4) notebook or desktop PC. The system is portable, so it is easy to use it in training camps or at competitions.

In order to obtain accurate data, some conditions of use must be met:

1) the camcorder should be positioned at a slight angle (ca. 30°) from one side of the athlete,
2) the camcorder should be positioned at a minimum horizontal distance of five metres from the athlete,
3) the camcorder should be positioned at a height from the floor that is approximately half of the maximal vertical distance of barbell motion (this point becomes less important when the horizontal distance from the camcorder is more than five metres),
4) a vertically aligned video image is necessary (the pixels of the image define the alignment of the coordinate system),
5) to minimise calibration errors, the athlete should fill the video image (zoom),
6) the shutter of the camcorder should be set to 1/125 s or less.

SYSTEM EVALUATION

When using measurement systems it is vital that scientific standards are met. Two of these standards are that measurements are reliable and valid. All results shown below are from experiments with the Realanalyzer. Because no general changes regarding barbell tracking and calibration procedure have been introduced, all results can be transferred to Realanalyzer HD.

Reliability
We checked interrater and intrarater (retest) reliability for the Realanalyzer using the ICC (Intraclass Correlation Coefficient) (11).
The tests were done as follows: for interrater reliability three researchers from the weightlifting research group at the IAT analyzed 30 attempts each from a video clip (10 attempts snatch, 10 attempts clean, 10 attempts jerk); for intrarater reliability one researcher from the weightlifting research group analyzed 30 attempts from video clips twice (separated by 1 month between first and second trial).

For the ICC three parameters were selected: one parameter for distance, one for velocity and one for acceleration. The coefficients for interrater (IRR) and intrarater (RR) reliability are: distance IRR = 1.000, RR = 1.000; velocity IRR = 0.987, RR = 0.994; acceleration IRR = 0.978, RR = 0.994. The results show a very high reliability for the calibration procedure, since this is the only part where errors can occur.

The slight deviation between distance and acceleration is from typical errors in calculation of the derivatives of distance coordinates. The Realanalyzer and Realanalyzer HD are therefore highly reliable systems.

Validity

When using only the Realanalyzer for biomechanical analyses in weightlifting, validity is not as important as reliability. As long as only one system is used, it does not really matter, how exact theses parameters are if the system always measures the same parameter (reliability). Validity comes into play if a researcher wants to compare results from one measurement system to another, or they are interested in how accurately a system measures a "real" parameter. Videometry is a gold standard for measuring distances.

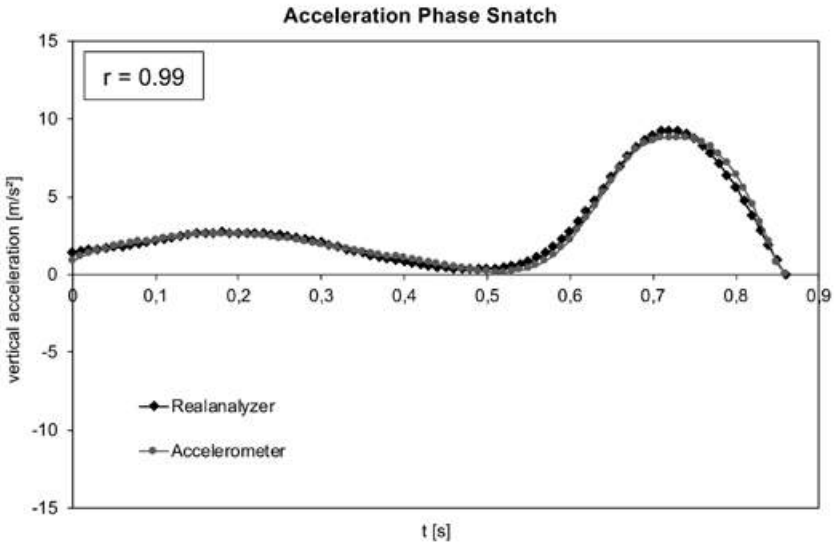


FIGURE 3: EXAMPLE OF COMPARISON OF VERTICAL ACCELERATION FROM ACCELEROMETER AND REALANALYZER FOR ACCELERATION PHASE IN SNATCH

There is no doubt that distances can be measured very accurately via video if the calibration is correct. It is more controversial to obtain acceleration data from videometry, since acceleration is just calculated (2nd derivative) from changes of distance over time. Many of these objections concern the frequency of video capturing. The Realanalyzer works with a standard video frequency of 50 Hz. To check whether 50 Hz is suitable to accurately measure acceleration from videometry we compared calculated barbell acceleration from the Realanalyzer (@50 Hz) to measured barbell acceleration from an accelerometer (@100 Hz) in the acceleration phase of snatch and clean (10). To match the data frequency of both systems, the acceleration data from videometry was interpolated with a cubic spline function to 100 Hz. Contrary to most concerns, the validity of acceleration from 50 Hz videometry is very good. As a specific parameter, we checked the difference for the maximum acceleration in the second pull. The mean difference for 20 attempts (10 snatch, 10 clean) was only 0.24 m/s . That corresponds to an error of 2.5% for maximum acceleration. More important, the correlations of time series data were very high with a mean correlation of r = 0.98 (fig. 3). Our results fit very well to data of Sato, Smith, Sands (12) who also compared an accelerometer to videometry in weightlifting. With these results in mind, interpreting barbell acceleration from Realanalyzer HD can be done with confidence.

PARAMETERS OF BARBELL MOVEMENT

The Realanalyzer HD is custom built for weightlifting. All important parameters and the video will be presented in diagrams and tables directly after the lift. With this information, the coach can rate the technique or the strength abilities of the athlete.

As already mentioned, the software automatically starts and ends tracking the lift. The coach or researcher only needs one click to run the measurement. That makes it very easy to handle, without having a big knowledge in computer science.

Table 1 lists all discrete parameters the software provides, together with a description. A data export of trajectory coordinates and velocity as well as acceleration time data makes it possible to calculate other additional parameters in Excel or MatLab.

	Parameter	Direction	Unit	Exercise	Description
	P_{SK}	Y	N • S	S,C,J	VERTICAL IMPULSE (BARBELL WEIGHT*V_{MAX})
DISTANCE	SV_{MAX}	X/Y	CM	S,C,J	COORDINATES OF MAXIMAL VELOCITY
	S_{AUFT} (S_{DIP})	X/Y	CM	J	COORDINATES OF LOWER TURNING POINT IN DIP
	SV_{AUFT} (SV_{DIP})	Y	CM	J	DIP DISTANCE TO V_{AUFT}
	S_{ZH} (S_{TP})	X/Y	CM	S,C,J	COORDINATES OF UPPER TURNING POINT
	SV_{MIN}	X/Y	CM	S,C,J	COORDINATES OF MAXIMAL DROP VELOCITY
	S_{SITZ} (S_{SIT})	X/Y	CM	S,C	COORDINATES OF SQUAT POSITION
	S_{AB} (S_{DOWN})	Y	CM	S,C,J	DROP DISTANCE
	S_{REST} (S_{RES})	Y	%	S,C,J	RELATIVE DISTANCE FROM END OF THEORETICAL TRAVEL DISTANCE TO UPPER TURNING POINT (RESIDUAL WORK)*
VELOCITIE	V_1	Y	$CM \cdot S^{-1}$	S,C	MAXIMAL VELOCITY AT THE END OF 1ST PULL
	V_2	Y	%	S,C	LOSS OF VELOCITY IN THE TRANSITION (END OF TRANSITION)
	V_{AUFT} (V_{DIP})	Y	$CM \cdot S^{-1}$	J	MAXIMAL DIP VELOCITY
	$_{VMA}X$	Y	$CM \cdot S^{-1}$	S,C	MAXIMAL VELOCITY AT THE END OF 2ND PULL / END OF THRUST
	$_{VMI}N$	Y	$CM \cdot S^{-1}$	S,C	MAXIMAL DROP VELOCITY AT THE END OF TURNOVER
FORCE	$_F1$	Y	%	S,C	MAXIMAL FORCE (M*A) IN 1ST PULL, IN PERCENT TO BARBELL LOAD
	$_F2$	Y	%	S,C	MINIMAL FORCE IN TRANSITION, IN PERCENT TO BARBELL LOAD
	$_F3$	Y	%	S,C	MAXIMAL FORCE IN 2ND PULL, IN PERCENT TO BARBELL LOAD
	F_{AUFT} (F_{DIP})	Y	%	J	MAXIMAL FORCE IN DIP, IN PERCENT TO BARBELL LOAD
	F_{STOSS} (F_{THRUST})	Y	%	J	MAXIMAL FORCE IN THRUST, IN PERCENT TO BARBELL LOAD
	F_{BR}	Y	%	S,C,J	MAXIMAL BRAKING FORCE IN CATCH, IN PERCENT TO BARBELL LOAD
TIME	T_{UMGR} (T_{TURN})		MS	S,C,J	TURNOVER TIME, TIME FROM V_{MAX} TO V_{MIN}
			MS	J	TIME FROM VDIP TO V_{MAX}

* TRAVEL DISTANCE (TD) = V_{MAX}^{2} / 2G

S_{RES} = (STP[Y]-(SV_{MAX}[Y]+TD)) / (TD*100)

TABLE 1. DISCRETE PARAMETERS FOR BARBELL MOVEMENT
(ENGLISH PARAMETER TRANSLATION IN PARENTHESES; S = SNATCH, C = CLEAN, J = JERK)

PRACTICAL APPLICATION

Because of the immediate biomechanical information on barbell movement, the Realanalyzer HD is a standard tool in almost every training session of the German national team.

The system supports the everyday work of the coaches. However, the reader should bear in mind that the software only provides data. The interpretation of the data is the job of the coach or researcher. If someone uses a wrong approach to correct an error, the system will not help. Although the Realanalyzer HD is a very easy to use biomechanical tool for barbell analyses, when working with the system some notes should be made in advance to avoid incorrect interpretation:

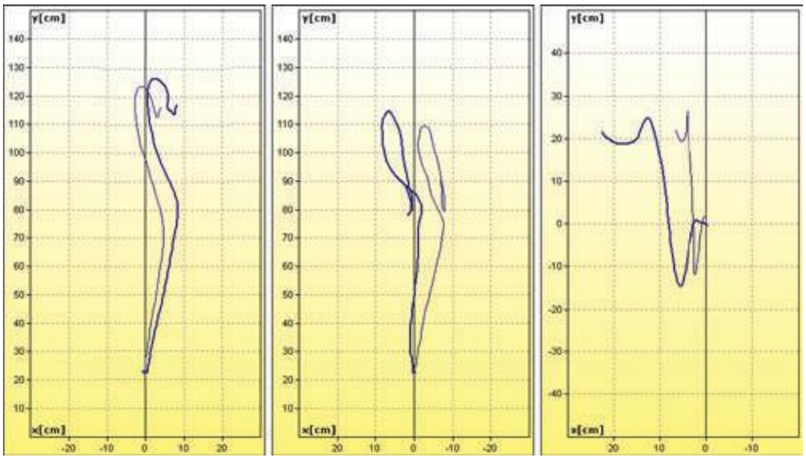


FIGURE 4: THREE TYPICAL EXAMPLES OF TWISTED BARBELL SIDES FOR SNATCH (LEFT), CLEAN (MIDDLE) AND JERK (RIGHT). THICK LINES CORRESPOND TO LEFT BARBELL SIDE, THIN LINES CORRESPOND TO RIGHT BARBELL SIDE.

1) The systems only tracks one side of the barbell. Rossi, Buford, Smith, Kennel, Haff, Haff (9) report that in their study no differences between the right and the left side of the barbell are present. Unfortunately, this is not a generalizable result, because many athletes do not show identical barbell trajectories from both barbell sides. Often you will find a twist between the right and the left side of the barbell (fig. 3). To correctly interpret a trajectory and to give purposeful feedback to the athlete, make sure that a "wrong" trajectory is not the result of a twist of the barbell.
2) The non-identical barbell movement from the left and the right side of the body will reflect in the discrete parameters too. Often discrete parameters differ between left and right. Therefore, we recommend determining individual profiles of an athlete for both the left and the right side.
3) The measured barbell kinematics are influenced by oscillations of the barbell during the lift. With increasing barbell weights the oscillations become more dominant and influence the outcome, especially at points where high accelerations occurs.
4) The software has an automatic lifting phase recognition based on the time series data from trajectory coordinates, velocity and acceleration. Sometimes the recognition algorithm does not find the correct position and thus calculates a parameter wrongly. Make sure that the calculated values are sensible before giving feedback. With an editing function, the user of the software can change specific values if necessary.

REFERENCES:

1. Hiskia G. Biomechanical analysis on performance of world and olympic champion weightlifters. In: Lukacsfalvi A, Takacs F, eds. Proceedings of the weightlifting symposium 1997 ancient olympia/greece. Budapest: International Weightlifting Federation; 1997:137-158.
2. Jentsch H. Weightlifting Analyzer 3.0. Paper presented at: 10. Frühjahrsschule "Informations- und Kommunikationstechnologien in der angewandten Trainingswissenschaft"; April, 2008; Leipzig.
3. Kipp K, Giordanelli M, Geiser FC. Predicting net joint moments during a weightlifting exercise with a neural network model. Journal of Biomechanics.2018.
4. Kipp K, Harris C. Associations between ground reaction forces and barbell accelerations in weightlifting. In: Sato K, Sands WA, Mizuguchi S, eds. 32 International Society of Biomechanics in Sports. Johnson City2014:782-785.
5. Kraemer WJ. Exercise prescription in weight Training: A needs analysis. National Strength and Conditioning Journal. 5(1):64-65;1983.
6. Reiser RF, Smith SL, Rattan R. Science and technology to enhance weightlifting performance: the Olympic program. Strength & Conditioning. 18(4):43-51;1996.
7. Richter G. Ein Trainergerät zur Objektivierung der sportspezifischen Schnellkraftfähigkeit und zur Trainingssteuerung im Gewichtheben. Theorie und Praxis Leistungssport. 11(3):241-263;1973.
8. Richter G. Zu Problemen und technischen Möglichkeiten einer erhöhten Aussagefähigkeit der Kinematografie. Theorie und Praxis Leistungssport. 212287:111-115;1973.
9. Rossi SJ, Buford TW, Smith DB, Kennel R, Haff EE, Haff GG. Bilateral comparison of barbell kinetics and kinematics during a weightlifting competition. International Journal of Sports Physiology and Performance. (2):150-158;2007.
10. Sandau I, Lippmann J. Validierung der Beschleunigungsmessung an der Hantel – Realanalyzer (IAT) vs. VmaxPro (B&M Sports Technology). Leipzig: IAT; 2015.
11. Sandau I, Lippmann J, Jentsch H, Seidel I. Reliabilität des Realanalyzer, ein 2-D-Messsystems zur Echtzeiterfassung der Hantelbewegung im Gewichtheben. Poster presented at "NeuroMotion" Aufmerksamkeit, Automatisierung, Adaptation; 2012; Münster.
12. Sato K, Smith SL, Sands WA. Validation of an accelerometer for measuring sport performance. Journal of Strength and Conditioning Research. 23(1):342-347;2009.
13. Stone MH, O´Bryant HS, Williams FE, Johnson RL, Pierce KC. Analysis of bar paths during the snatch in elite male weightlifters. Strength & Conditioning. 20(4):30-38;1998.
14. Worobjew. Tribuna Masterow Tjascheloi Atletiki. Moskwa: Fiskultura i Sport; 1965.
15. Zekov IP. Biomechanik der Gewichtheberübungen. 2 ed. Leipzig: DHfK; 1976.

INGO SANDAU

Institute for Applied Training Science, Leipzig, Germany, Weightlifting Research Group

MICHAEL BUNK

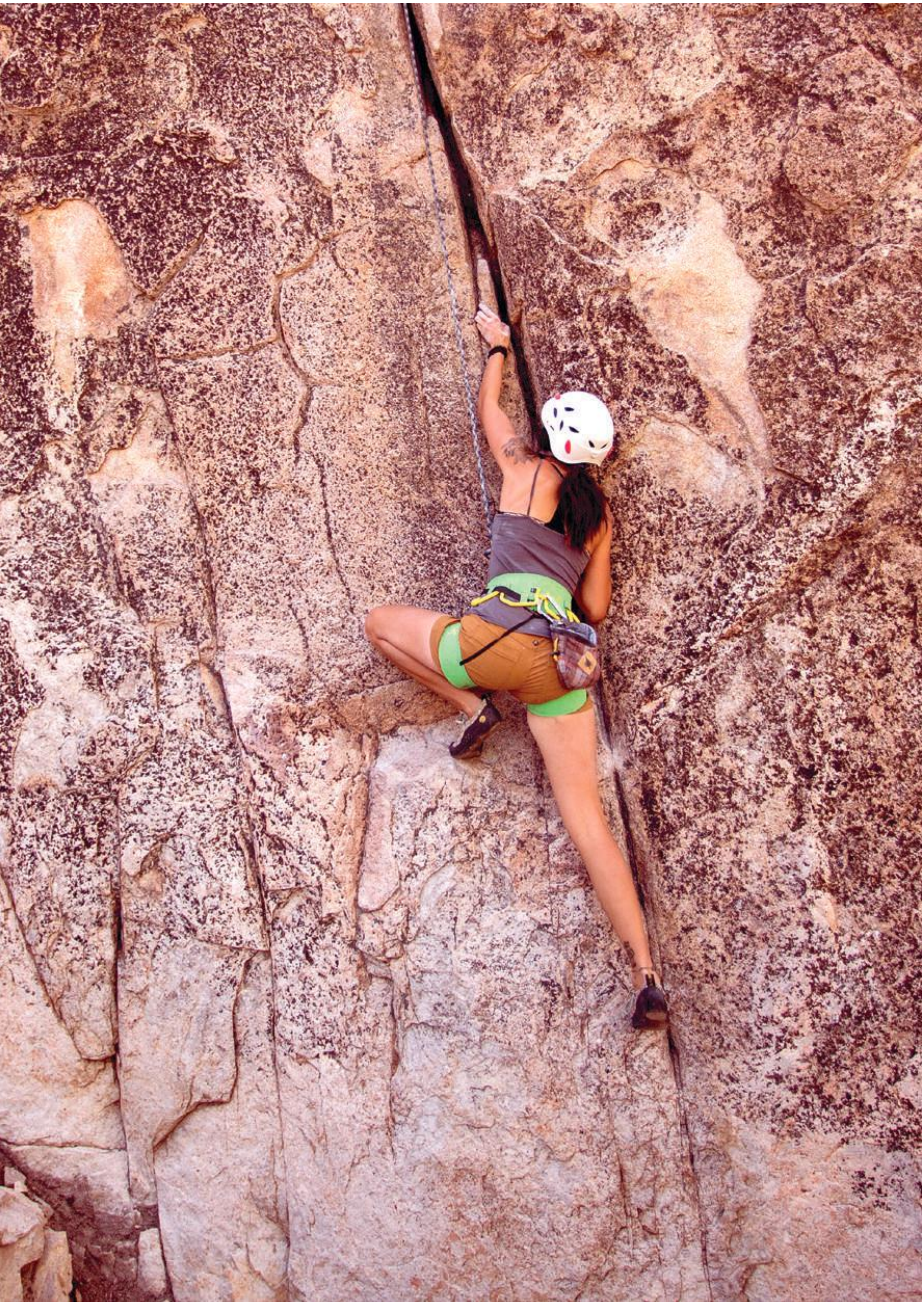
Institute for Applied Training Science, Leipzig, Germany, Sports Computer Science Research Group, Leipzig, Germany

HOLGER JENTSCH

Institute for Applied Training Science, Leipzig, Germany, Sports Computer Science Research Group, Leipzig, Germany

APPLAUDING A LIMIT TO ESTABLISH A VICTORY

BY ANTONIO URSO



The title of this article would appear to contain the juxtaposition of contradictory terms: such a mismatched title that getting past the terms is the only way of re-establishing the norm. Winning, in fact, is often a question of exceeding a limit. Limits tie you down, hold you back, therefore overcoming them means going beyond, towards something greater, towards supremacy. Victory lies beyond limits. Many reach the limit, few manage to leave them behind. Limits are actually great starting points and not only in the world of sport; limits are, in fact, the condition from which the greatest achievements of the human race are intertwined. A limit, which inevitably always contains a measure (be it only glimpsed or reached), is that aspect of the human being that tells us a lot about ourselves and about the approach we implement to try and raise the bar of our progress.
Limits have a lot to do with the concept of freedom. It is precisely the illusion of being free that often gives us the feeling of having no limits. Our "indeterminateness", for instance, with respect to the rest of the animal world, gives man the illusion of boundless goals, completely different to the typical determination of animals. To give a simple example - a man can easily live at the North Pole as well as in Africa: it would be difficult for a lion to do the same. A lion, by nature, has few environmental, social, food and survival choices, its limits are absolutely clear and it is difficult to imagine a different condition, or a determination to change, to go beyond, to look for a new condition, a new way of being. One would say that in the animal world, in cognitive terms, everything is wired. A baby zebra or newborn wildebeest, in a matter of hours, already knows what to do, how to interact with the group, and, instinctively, knows it has the tools (obviously not all, but those determined by nature) for survival. Their limitation is that of being able to do everything possible knowing the limits, the limits of their actions: the limits placed on their choices and on behaviour.

Humankind is born only with a small part of wired cognitive ability, that is relative to the primary needs of survival: eating, sleeping and receiving affection. Human beings have many more parts to be written, unknown to be made known, the sheets to be filled are actually the majority. An authentic blank canvas which will be filled mainly through two substantial and decisive contributions: the encounters we make in life and the experiences that they impress on us. And it is here that extraordinary chapters of original and unique experiences open up. From the encounters and the experiences that each human being makes, the sense of limits is constructed which, as a consequence, can become oversized, can be balanced or can manifest itself as undersized. And it is from said encounters and experiences that each of us makes that we build our own culture of limits.
Man is not able to generate himself, let alone make himself, but rather he builds his identity from others and with others and he builds his own limit together and with the contribution of others.
In today's highly individualistic society, I do not find it hard to understand that words like these definitely go against the tide. Nor to realize that, in a society dominated by narcissism and out of bounds in every sense, writing (and thus affirming) that limits are actually our salvation, assumes an antithetical position. But is this not perhaps the truth, a truth which is very well known from the classical Greek world: the 'right measure'? That 'Katà Métron", as they said, the true containment of desire, of the expansive force of life which, without measure, pushes men to want what is not in their power, thus nurturing their overindulgent "demon".
The Greeks also associated the right measure with the concept of happiness, with their own inner disposition (eu-daimonia), with happiness and its pursuit, which presumed one was aware of, or knew one's own demon (one's limit), since - otherwise - the fruit of the mismanagement of oneself and one's own strength, clouded by the voluptuousness of desire (kako-daimonia), would inevitably have led to the opposite - unhappiness. For the Greeks, therefore, happiness as the satisfaction of desire; and - mind you - not happiness as a reward for virtue, but virtue itself, as the ability to govern oneself for one's own success. In this sense, happiness can basically be taught.

Today, having scaled down, and in some cases, pulverised the value of limits has meant that even the "law", therefore ethics, for which even rules and whoever enforces them, has suffered a diminutio, an impoverishment which up until some time ago was frankly unimaginable. There are not nor there cannot be social or community rules if there is no knowledge of the limit, if there is no knowledge of one's real abilities or of the abilities of an entire society. The loss of limits is equivalent to the loss of direction. The recognition of limits makes the path, the direction, the route to the destination an equivalent. In our specific case, we could say, in terms of sport, the journey, the path to and for victory. Our society is more often than we can imagine outside the limits.

The out of bounds, moreover, is always in contrast with the search for desire. In the out of bounds there is always the illusion that nothing is lacking. Those who live in the out of bounds live with the rapid and irrational satisfaction of the fulfilment of a need. The need, which lives according to rigid rules, can never be satisfied with anything other than the onset of the same, it can never be fully satisfied as once satisfied, it sets in motion the mechanism of repetition. In short, needs never fully satisfy our existence and this is obviously well known to advertising experts who take full advantage of it.

Another characteristic of needs is that they can be temporarily satisfied also by things or objects: the need therefore would seem to omit the necessary presence of the other, as opposed to desire that is always lacking and is always and only realised through the other in the full determination of a limit, within the boundaries of law!

How does this translate into sports?
The world of sport is not exempt or detached from the concept of out of bounds. Modern sport was born culturally and methodologically with the concept of out of bounds. When the old political and social organisation of the former Eastern bloc decided to approach the world of Olympism, Russian physiologists conceived the key concept of training as rigid, well-defined and doing more, always more: it was precisely this idea of "more" that already represented the concept of out of bounds.

Obviously, if the method to be applied was already out of bounds, it certainly could not be applied to athletes who respected their limit. There would have been a contradiction in being irreconcilable. An out of bounds method precluded the cancellation of the limit of those who embraced it in training. Modern sport has developed with this approach and with it we have also achieved results that obviously represent nothing compared to all the lost medals and in particular compared to the millions of boys and girls who have abandoned the sport with a sense of powerlessness, because they felt totally inadequate in the out of bounds territory that forced them to do much more than simply practicing a sport.

It certainly provides plenty of food for thought! It would take a school of philosophy, psychology and pedagogy to study this topic of limits and the subsequent culture within the whole world of sport. It is from knowledge of limits that training is built, which individualises training. It is in compliance with limits that conditions are created to transform training from a need into a desire. It is in respect of limits that we have respect for the time and space it takes to create a performance, to build personal and sporting growth. Man is this way only within limits. He does not lower it, on the contrary he raises and exalts it.

In this historical moment, saturated with the concept of performance, deriving moreover from an era defined as "technological", the out of bounds has found, if ever there had been a real need, further application and renewed vitality.

The "technological" era can be considered the era of the most rational thought that has ever existed, realised with the maximum profit at the lowest cost. The mother of all out of bounds. It is precisely this culture that raises the level of performance in all fields and that excludes all those who lie outside performance. The excess of performance, the continuous demand for performance establishes the out of bounds as a way of life. Dramatic!

This aspect, which is completely influential in the quality of life of many of us, has even produced new pathologies and changed the mechanisms that previously generated already known pathologies, thus increasing their numbers.
The new pathologies generated by the inability to manage performance stress has also triggered obvious changes in direction at the cultural level. Today, those who are unable to manage life as an absolute performance are not taken into consideration by society; you are out of society, somehow outside the limits of a society that is already out of bounds!
School itself has been transformed from a place of learning to a place of performance. Everything has become performance.
Sex is no longer an element of pleasure, but a performance. Work is no longer a place of creation, but measured in terms of performance. Performance also in art, in music.

Performance even in affection. Martin Heidegger, (1889 - 1976) a German philosopher who had realised in the years of the development of technology of the Nazi regime what nefarious developments he would have projected into the future wrote: *"What is really disturbing is not that the world will transform into a complete domain of technology. Far more disturbing is that man is not at all prepared for this radical change in the world. By far the most disturbing thought is that we are not able to reach, through meditative thought, an adequate comparison with what is actually emerging in our age".*
In short, I add, unfortunately we do not have an alternative thought to the rational thought of technology.

We cannot create other values because we were not ready for this rapid cultural transformation. Not having other values in which to believe produces nihilism and, even if Friedrich Nietzsche (1844 - 1900) was capable of predicting it about one hundred and thirty years ago, we still have not been able to find a solution to it. There is no remedy for out of bounds. Going beyond limits led to the extinction of extraordinary peoples such as the Greeks and Romans.

So for the world of sport that is based on performance, how can we return to the value of limits?

I would like this question to provoke discussion among our readers, and in a subsequent issue we will publish the points of view of the protagonists of the sports world.

REFERENCES:

1. Brooks M., Oltre il limite - Le Scienze su licenza Codice Edizioni, Torino - 2015
2. Galimberti U., Psiche e techne - Feltrinelli Milano collana Universale economica Saggi - 8° edizione Novembre 2011;
3. Galimberti U., L'ospite inquietante. Il nichilismo e i giovani - Feltrinelli Milano collana Serie Bianca - Dicembre 2008;
4. Galimberti U., I miti del nostro tempo - Feltrinelli Milano Collana Universale economica Saggi - Novembre 2013;
5. Heidegger M., Essere e tempo - Longanesi Milano; collana I grandi lobri - 3° edizione settembre 2005
6. Recalcati M., L'uomo senza inconscio - Raffaello Cortina Editore Milano - 2010
7. Recalcati M., Cosa resta del Padre - Raffaello Cortina Editore Milano - 2011
8. Recalcati M., Ritratti del desiderio - Raffaello Cortina Editore Milano - Collana Temi - 2018
9. Wilson E. O., Il significato della esistenza umana - Le Scienze su licenza Codice Edizioni, Torino - 2014

Courtesy of

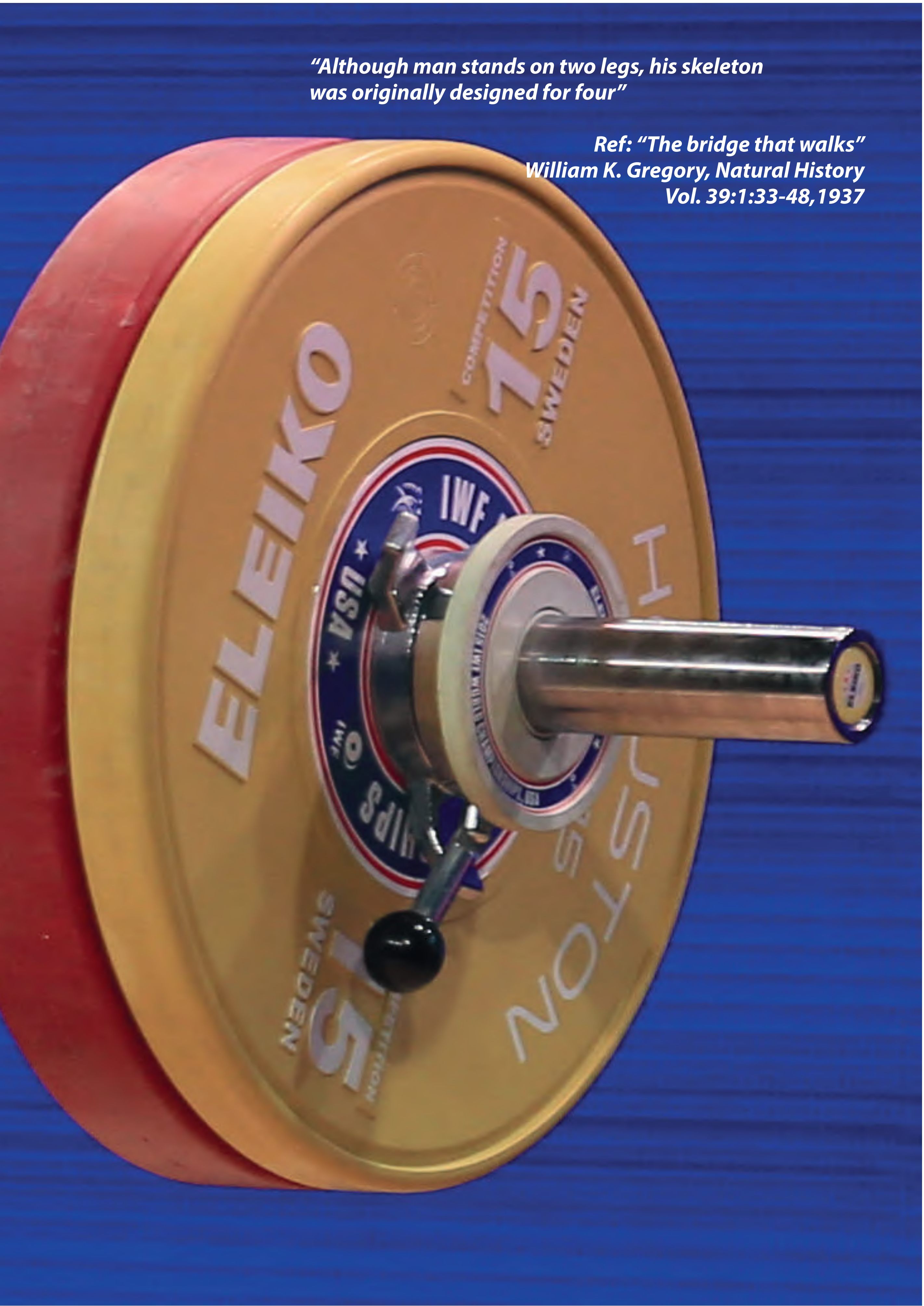
SPORTIVNY PRESS
SINCE 1982

TRAPS, BATS & CALVES: CONSIDERATIONS FOR THE HUNGARIAN START

BY ANDREW CHARNIGA

"Although man stands on two legs, his skeleton was originally designed for four"

Ref: "The bridge that walks"
William K. Gregory, Natural History
Vol. 39:1:33-48,1937



The lumbar area of the spine is the most common site of pain and injury for the weightlifter; with the shoulder girdle a close second (A.N. Vorobeyev, 1978; 1988).

"Lumbar pain most often is the cumulative result of many workouts. It may be that there is not one athlete who has not experienced lumbar pain after training more than 4 – 5 years." A. N. Vorbeyev, 1988

That being said, given the brevity of the classic exercises, even with maximum weights, the disposition of the body's links in the starting position of the snatch and the clean and jerk are critical. All of the Soviet era textbooks and numerous papers have covered this important element of the weightlifter's technique.

Nonetheless, the research of the starting disposition of the weightlifter's links (shin, thigh, trunk) has been focused for the weightlifter to adopt such a posture to generate the most effective force to separate and accelerate the barbell in the pull. And, this research has centered around the optimal disposition of the feet, shins, thighs, trunk, hand spacing and so forth; through biomechanical measurement of various postures (Kanyevsky,1983).

The dimensions of the barbell are fixed, i.e., the height of the bar from the floor is a constant; conditions are the same for everyone. Consequently, regardless of the relative of lengths of the athlete's trunk, arm and leg; the larger the knee angle at the start the greater the trunk is tilted closer to the horizontal and vice versa; the smaller the knee angle, the more the disposition of the trunk is towards the vertical.

Therefore, the relative stress (moment) on the legs varies with the degree of knee bend: the more the knee and ankle joint are flexed the larger the loading of the legs; the smaller the loading moment on the back, and vice versa.

With a very low start, i.e., a knee of angle 50° for instance, the hips will shift the greatest distance during the pull phase of the classic exercises.

Conversely, with a large knee angle at the (high) start, the greater distance the shoulder joints shift during the pull phase; and with this movement, the larger the strain on the lumbar spine. The reason being the trunk is almost vertical with a very low, i.e., Hungarian start, knee angles of up to 50° and about horizontal with high start, when the knee angle is 135. (Zhekov, I.P. 1976).

A general rule of thumb: the closer a link to the vertical, the lower moment; and vice versa; the closer to

FIGURE 1: FEMALE LIFTER PERFORMING ISOMETRIC BACK EXERCISE, TYPICALLY ASSOCIATED AS A MEANS TO COPE WITH THE LUMBAR PAIN FROM WEIGHTLIFTING TRAINING. CHARNIGA PHOTO.

FIGURE 2: SIX SOVIET WEIGHTLIFTERS (3 – OLYMPIC CHAMPIONS) AT THE 1972 BALTIC CUP. NOTE THE RELATIVELY LARGE TRAPEZIUS DEVELOPMENT AND WITH ONE EXCEPTION THE RELATIVELY SMALL DEVELOPMENT OF THE CALF MUSCLES RELATIVE TO THE THIGH MUSCULATURE, I.E., THE SHAPE OF A BASEBALL BAT. THE PHOTO EVINCES LESS BENDING AT THE ANKLE FROM A LARGE LOADING OF POWER SNATCH, POWER CLEAN, PULLS AND SO FORTH; WHICH IN TURN, IS INDICATIVE OF THE MINOR ROLE IN THOSE DAYS ASSIGNED THE CALF MUSCLES/ACHILLES TENDONS IN WEIGHTLIFTING TECHNIQUE. TOMMY KONO PHOTO.

the horizontal the larger the moment. For all practical purposes this means, at the larger knee angles characteristic of a high start there is proportionally greater shear strain on the lumbar area of the back, i.e., the weightlifter's weak link. The area most often the site of pain and injury. And, conversely, there is less strain in the lumbar area with smaller knee angles.

Furthermore, it is common knowledge an athlete's muscular topography is a reflection of the relative stress the various muscles are subjected in the performance of exercises; especially to the peculiarities of his/her technique.

Consider the contrasting development of thigh to shank musculature depicted in figure 2. The huge trapezius development and the noticeably disparate development of the shank relative to thigh muscles is a reflection of the relative importance Soviet weightlifting sport science assigned these muscle groups. Power snatch, power clean and pulls comprised a relatively large volume of the training load of those days.

Consequently, with a lot of pulling, shrugging of shoulders and half bending of knees one obtains the development depicted in the photo of messrs. Rigert, Kurentsov, Shari, Ryzhenkov, Sychev and Kolotov. Although Soviet times are long gone, the ideas of how to train, including the relative importance of the various muscle groups continue to this day.

Now, contrast the the lower extremity musculature of two Olympic champions in figure 3 with those of the Soviet lifters in figure 2. The large mass of the calf musculature, relative to thigh muscles, is an indication these muscles are heavily used in weightlifting exercises. So, it is no coincidence both athletes in figure 2 lift from the Hungarian start position, i.e., with fully flexed legs (Charniga, 2016).

The muscles of the shank (calf), especially soleus, are heavily involved in straightening the lower extremities from fully flexed knees; all the more so when the ankles are tilted significantly forward.

The development of calf musculature depicted in the figure is due to the inertia coupling phenomena. Quadriceps, gastro – soleus and other single joint plantar flexor muscles are synergists. The soleus muscle in particular, produces a counterclockwise torque on the shin which is coupled with the clockwise torque the quadriceps muscles exert on the thigh.
Consequently, athletes who use the

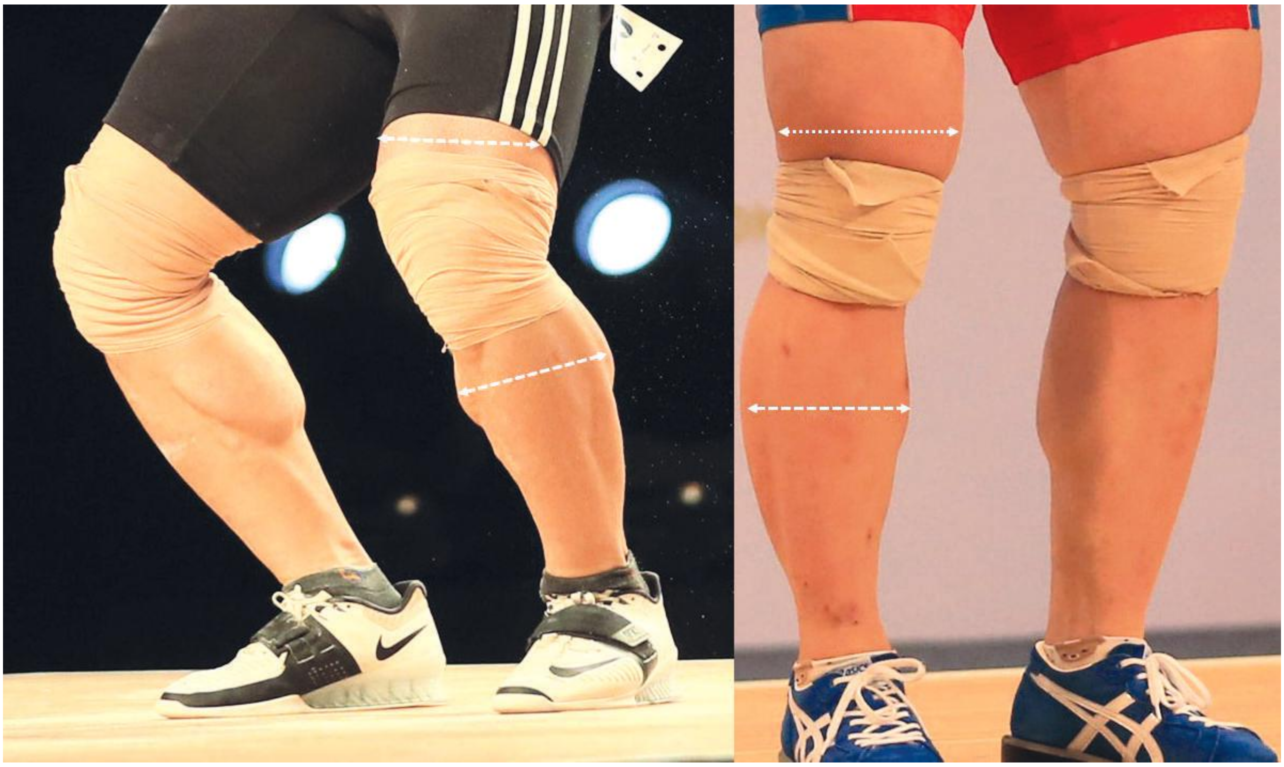


FIGURE 3-4: Note the large mass of calf muscles compared to thigh of the Olympic champions in figure 3. A male Olympic champion is on the left; and, a two time Olympic gold medalist female is on the right. Both employ the 'Hungarian' start, i.e., with fully/or nearly flexed lower extremities (figure 4). The relatively huge development of calf/shank musculature is an indication these muscles are heavily loaded over a large amplitude of movement in rising from this low position. Charniga photos.

" ...the highest retro-patellar compressive forces and stresses (at knee joint) can be seen at 90°".

Hartman, 2013

Hungarian start accentuate the muscles of the shank in the pull; which in turn, tends to lessen the loading on the lumbar spine. The reason being the trunk is in more vertical disposition at the beginning of lifting than would be the case with a classic or large knee angle in the start.

The fact of the matter is, the skeleton of a four legged animal is designed like a cantilever bridge for walking on four legs (Krogman, 1951). Conversely, the human spine evolved with cervical, thoracic and lumbar curvatures is designed to accommodate the vertical stresses connected with walking/running on two legs.

A logical effort to lessen the loading on the lumbar spine to lift big weights is a positive in both the short term and long term well being of the weightlifter.

An optimal disposition of the weightlifter's links (trunk, thigh, shin) in the dynamic start, defined as the instant of barbell separation (IOS), occurs when knee angles are in the range of 110 – 130° at IOS (Zhekov, 1976).

However, according to Zhekov, 1976, the knee angle at the start should be no less than 90°. So, why would one fully flex knees in the start and consequently begin lifting the barbell from a weak position?

KNEE PAIN AND DEPTH OF SQUATTING

Although knee injuries are not the plague of the weightlifter like the lumbar problem; knee pain is. Consequently, another factor to consider in weightlifting technique is the relationship between knee pain and depth of squatting.

Many coaches and athletes believe fully flexing the lower extremities places more strain on the knee joints. This of course means the opposite to be true: compression stress on the knee reaches maximum at a knee angle of 90°; subsequently it falls as the knee and ankles are fully flexed (Hartman, 2013). So, in point of fact, fully flexing lower extremities subjects the knees to less, not greater strain.

Power snatch, power clean and other such movements where the lifter stops the descending body – barbell unit, not only place the highest strain on the knee joints; but are the principle source of knee pain. One need only glance around an international training hall and see the proliferation of knee wraps and bandages, pain tape and so forth to recognize knee pain is a common affliction for the weightlifter.

Starting from knee angles of 90 – 110° accentuates strain at the knee when performing power snatch and power clean. The athlete proceeds from overcoming the resting inertia of the barbell from the starting position to stopping the bodyweight/barbell system at approximately the same knee angles, i.e., from large strain to larger strain at the knee. See figure 5.

FIGURE 5: ILLUSTRATION OF KNEE ANGLE IN THE CLASSICAL START CONTRASTED WITH APPROXIMATELY THE SAME ANGLE OF KNEE JOINTS WHEN THE MOVEMENT IS FIXED IN THE POWER CLEAN.

FIGURE 6-7: Elite female beginning to lift from a Hungarian start with significant tilting of shins. Note as she begins lifting knee angle increases from 70 to 98°; whereas the hips rise and the change in hip angle is negligible; from 63 – 65°. Charniga photos.

Consider for a moment the female in figures 6-7 pulling from a Hungarian start. An obvious motion without movement occurs from the beginning of the effort to the instant of barbell separation (IOS). The athlete's legs are working almost isometrically over a rather long period to bend the bar up to IOS. The tendons and ligaments accumulate strain energy in synchrony with the elastic bowing of the bar as this proceeds. The release of this strain energy can coincide with the elastic recoil of the bar to enhance the muscular contraction of the leg muscles.

Notice the young woman's hips rise faster than shoulder girdle; all the while the barbell remains on the floor. One still hears the adage that the hips, shoulders and barbell should rise simultaneously in the lifting from the floor. This inaccuracy continues despite the fact that hips rise faster than barbell and shoulders, regardless of the knee angle at the start; a phenomena first observed by Luchkin in the 1940s (Verkovsky, 1963).

There is a longer period of motion without movement with the Hungarian start because the muscles of the lower extremities are working at a mechanical disadvantage, applying force initially at knee angles as small as 50°.

Although no research exists in support, one could argue the strain energy in the lower extremities can be effectively released later in synergy with the recoil of the barbell; conceivably overcoming the mechanical disadvantage of the low start.

Another consideration, although not proven with facts and figures is the growing success of the increasing numbers of athletes employing the Hungarian start. More often than not these athletes are from Asia. And, there is no doubting the rising dominance of Asian lifter on the international scene. For instance, the female Asian lifters won 8 of 10 classes and males 7 of 10 at the 2018 world weightlifting championships.

According to Druzhinin (1974):
"Typically the athlete – barbell system shifts backwards from the vertical during the lift up to knee level. The athlete's body instead of the barbell shifts backwards with a high starting position; only the barbell shifts backwards with a medium starting position; and, with a low start the barbell shifts backwards and the body forward."

Druzhinin's observation that the barbell shifts backwards while body moves forward when the weightlifter employs a low start (Hungarian) is consistent with various observations of the reactive nature of modern weightlifting technique: there is more movement of the body and it's individual links than is considered acceptable with the classic model (Charniga, 2015).

A comparison of different start postures:
- *High start, with a large knee angle from 107 – 112° is the most advantageous* (Verkovsky, 1963)

Negatives:
- disproportionate loading on the lumbar spine;
- leg muscles perform work over a smaller amplitude of motion (Verkovsky, 1963);
- force generated by the legs slows significantly as barbell reaches mid – shin height (Verkovsky, 1963);
- a vertical disposition of the shin occurs sooner in the pull, i.e., the force arm of gravity reaches maximum sooner because trunk is almost horizontal (Verkovsky, 1963);
- prolonged lifting with a disproportionate loading on the back is connected with lumbar pain, or injury.
- / Classic start with barbell separation at a knee angle of 110 – 13°

- a dynamic start (instant of barbell separation) with a knee angle of 110 – 130° can be considered optimal because the loading moments on trunk and leg levers are smallest (Zhekov, 1976);

- less loading on the lumbar area; but ankles quickly assume vertical, loading shifts disproportionately to back.

- Hungarian start
- least strain on lumbar spine of the three variants;
- less strain on knee joints;
- compression stress on the knee is further mitigated as the athlete shifts through knee angle of 80 – 110° with inertia rising from the low squat;
- prolonged static strain in the lower extremities up to IOS may be recouped as elastic recoil;
- possible advantages for balance and stability when the athlete fixes the weight, i.e., the lifter moves from a spatial orientation of 'squat to squat'.

The official journal of the European Weightlifting Federation

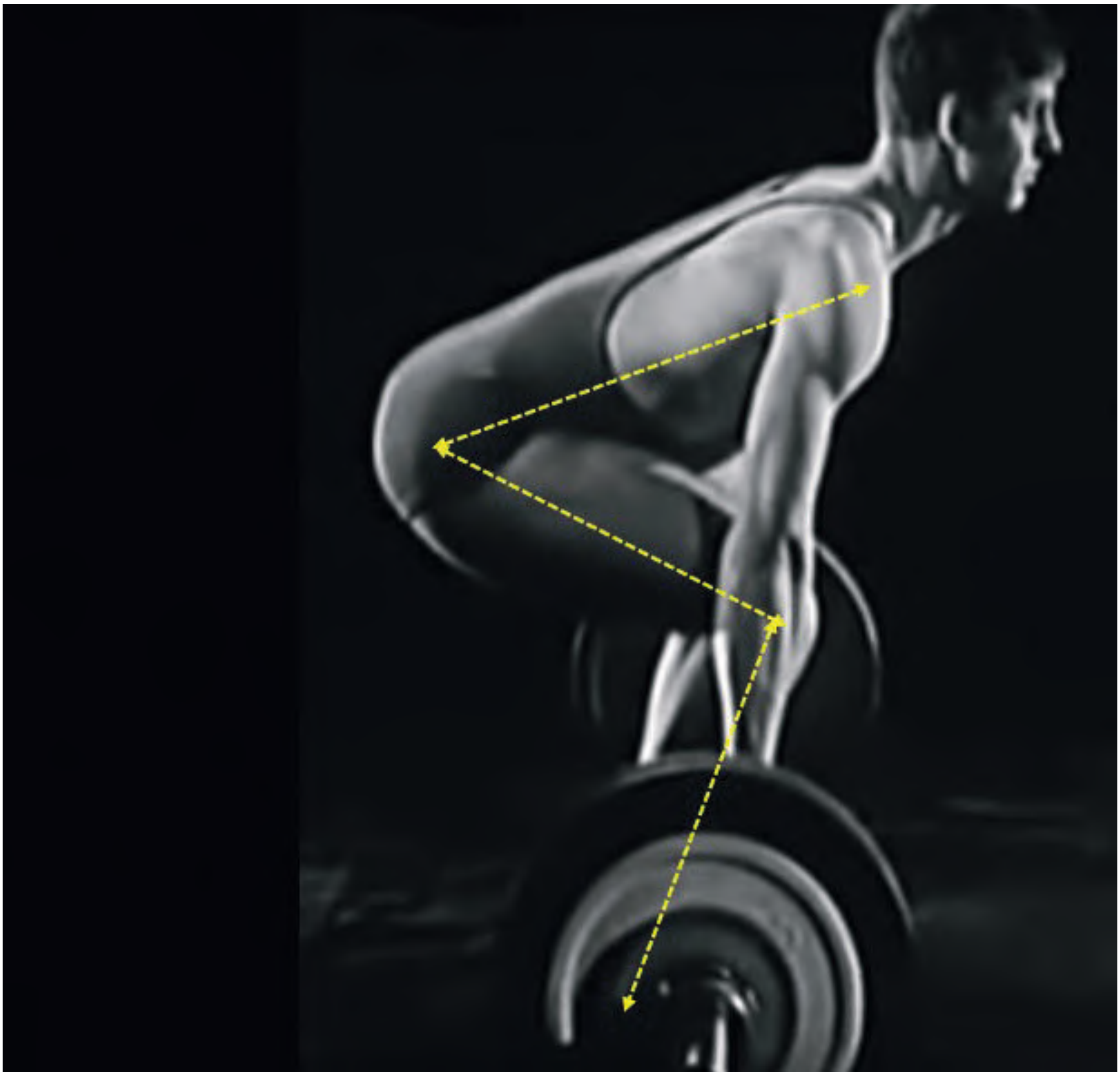


FIGURE 8: CONTRASTING DISPOSITIONS OF SHIN, THIGH AND TRUNK FOR CLASSIC START (ON THE LEFT) AND HUNGARIAN START (ON THE RIGHT).

CONCLUSIONS

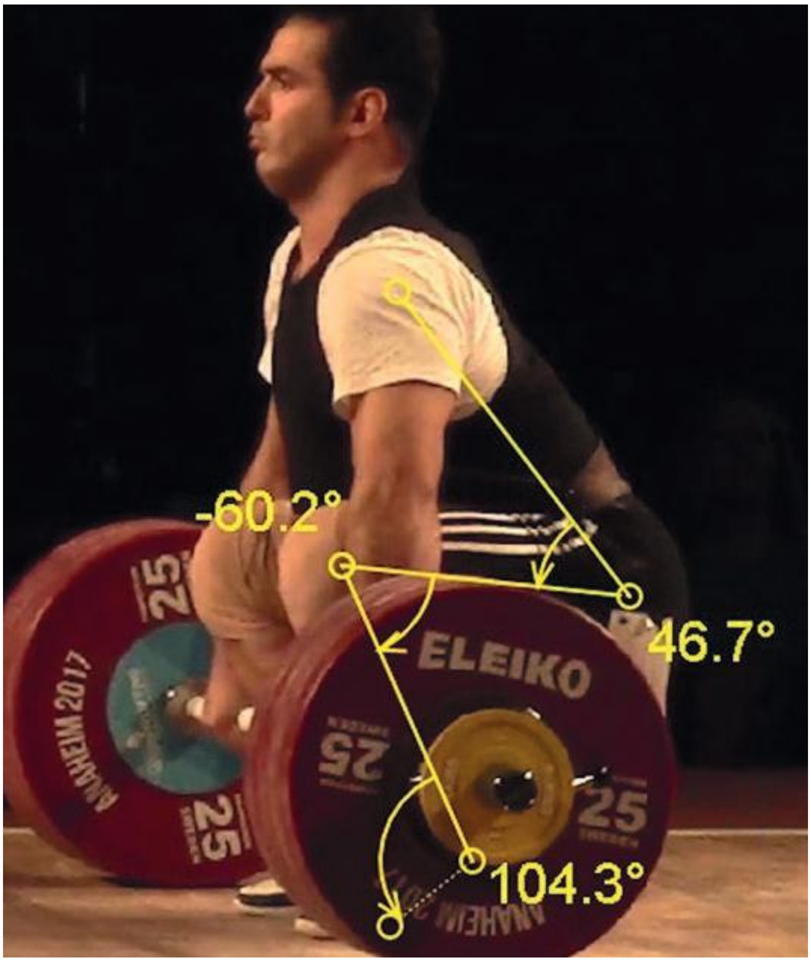
Two major sources of pain, injury or just discomfort for the weightlifter occur at lumbar spine and knee joints. The lumbar problem can be connected with chronic straining with the trunk tilted significantly away from the vertical. In the same vein, knee pain can arise in connection with a large volume of significant straining over knee angles of 90 – 130°.

The starting position of the weightlifter for pull phases of the clean and the snatch is crucial to the successful execution of the exercises. A Hungarian start where one begins to lift from relatively small knee angles 50 – 80° with a disposition of the trunk closer to the vertical is the weakest disposition of the weightlifter's links to begin lifting the barbell. Yet this technique has distinct advantages for performance of the lifts as a whole.

The classic start from a knee angle of close to 90° and with a barbell separation within the 110 – 130° range involves the minimum moments on legs and trunk. The high start with large knee angle and trunk close to horizontal is strongest position with the least efficient use of the legs and the greatest strain on the lumbar spine.

Advantages of the classic and high start are connected only with the effectiveness of the force generated to separate the barbell from the floor. Not taken into account is the efficacy of the entire motion from pull to

N° 13 / May-August 2019



ANDREW B. CHARNIGA
WEIGHTLIFTING SPORTS SCIENTIST AND TRAINER WITH A DEGREE IN EXERCISE SCIENCE FROM EASTERN MICHIGAN UNIVERSITY (USA) AND A MASTERS IN KINESIOTHERAPY FROM TOLEDO UNIVERSITY (SPAIN). THE FOUNDER OF SPORTIVNY PRESS IN 1980, MR. CHARNIGA HAS ALSO EDITED 15 BOOKS TRANSLATED INTO RUSSIAN AND DOZENS OF ARTICLES ON WEIGHTLIFTING TRAINING, BIOMECHANICS, RECOVERY, ETC. HE REGULARLY PUBLISHES SPECIALISED ARTICLES AND TRANSLATIONS ON THE WEBSITE: WWW.SPORTIVNYPRESS.

descent and fixation of the barbell in the squat. An important factor to consider for lifters whom employ the classic and high start and incorporate significant volumes of power snatch, power clean and pulls in training is that these lifters begin the pull and stop at the nearly the same angles of knee and trunk, i.e., chronic stress from repetitive overload at joint angles where there is highest strain.

At least some of the aforementioned repetitive overload stress is mitigated when the weightlifter employs the Hungarian start. There is less strain with knees lifting from the fully flexed disposition. Furthermore, there is less strain on the lumbar spine as the trunk is closer to vertical, i.e., the closer a link tovertical the smaller the moment. A possible advantage of a Hungarian start would be the closer proximity of trunk to vertical; facilitating kinesthetic and spatial awareness of balance in fixing the the barbell in the low squat of the snatch and the clean, i.e., the lifting proceeds from squat to squat. The Hungarian start most effectively utilizes the potential of the all but forgotten muscles in the weightlifter's arsenal: the calf musculature.

References

1/ Vorobeyev, A.N., Weightlifting, Textbook for the Institute of Sport, FIS, Moscow, 1988, Translated by Andrew Charniga

2/ Vorobeyev, A.N., Weightlifting, FIS, Moscow, 1978, Translated by Andrew Charniga

3/ Kanyevsky, V.B., "The starting position in the snatch and the clean and jerk for weightlifters of differing body types", Dissertatsiia na coiskanie Uchenoi stepeni Kandidata pedagogicheskikh Hauk, 1983

4/ Zhekov, I.P., Biomechanics of the weightlifting exercises, FIS, Moscow, 1976.

5/ Charniga, A., "Can there be such a thing as an Asian pull?, www.sportivnypress.com

6/ Charniga, A., "The foot, the Ankle and an Asian Pull". www.sportivnypress.com

7/ Hartman, H., Wirth, H., Klusemann, M., "Analysis of the Load on the Knee Joint and Vertebral Column with Changes in Squatting Depth and Weight Load", Sports Med, (2013) ;43:993-1008 DOI 10.1007/s40279-013-007-6

8/ Krogman, W., "The Scars of Human Evolution", Scientific American Vol. 185:6:54-57, 1951 "Although man stands on two legs, his skeleton was originally designed for four" Ref: "The bridge that walks" William K. Gregory, Natural History Vol. 39:1:33 – 48, 1937

9/ Verkovsky, F., "The clean with a deep squat", Tribuna Masterov, Moscow, FIS, 1963:56 – 80. Translated by Andrew Charniga

10/ Druzhinin, V.A., "A rational model of the classic snatch", Teorii I Praktika Fiszicheskoi Kultury, 8:87-89:1974. Translated by Andrew Charniga

The official journal of the European Weightlifting Federation

EEG APPLICATIONS FOR SPORT AND PERFORMANCE

PART ONE

BY T. THOMPSON, T. STEFFERT , T. ROS , J. LEACH , J. GRUZELIER
EDITOR: MARCO IVALDI

INTRODUCTION

Ways in which we can improve sporting performance are of great contemporary interest. A survey in 1997 showed that nearly $12,000 million was spent on ergogenic aids and dietary supplements in the US, with approximately 50% of the general population having reported their use [1]. An alternative approach to understanding performance enhancement has been to study cerebralactivity through electroencephalography (EEG). If skilled performing in a particular field is associated with a distinctive EEG profile, this could help us to understand important cortical processesunderlying peak performance. In addition, the potential to optimise performance is offered by training an individual's EEG to increase or decrease in a desired direction by self-regulatory techniques such as EEG-biofeedback, also known as neurofeedback.

A recent article in Men's Vogue claimed that tennis champion Mary Pierce, Olympic gold-medal skier Hermann Maier, and several players on the 2006 World Cup winning Italian football team are all reported to have used neurofeedback to improve their performance [2], although few validation studies have been conducted.

In order to establish whether performance enhancement through EEG-biofeedback extends beyond anecdotal reports, well-controlled scientific studies are clearly required. However, our ability to make accurate inferences regarding links between EEG and performance is dependent upon our ability to obtain reliable EEG data. Unfortunately, recording EEG while the subject is in motion is inherently problematic.

All of the usual causes of EEG artifact (muscle potentials, sweating, electrode movement etc.) tend to be exacerbated during motion. Furthermore, additional problems such as equipment portability and restriction of the individuals' natural movement are also introduced.

The overall purpose of this article is to discuss the issues of motion-related EEG artifacts within the context of the sports sciences.

Firstly, we provide a brief overview of the basic principles of EEG. Secondly, we discuss how previous studies have attempted to apply EEG methodology to sports research. Thirdly, the problems that EEG recording in sports typically presents will be discussed along with practical, technological and computational methods for tackling these problems. Finally, we discuss whether attempts to alter an individual's EEG through neurofeedback have successfully resulted in performance enhancement.

THE BASIC PRINCIPLES OF EEG

The electrical activity of neurons in the brain produces currents that reach the surface of the scalp. EEG provides a non-invasive method of recording the voltage differences of these scalp potentials. These potentials are created by both cerebral sources and un-wanted non-cerebral artifacts which tend to be exaggerated during movement. The EEG signal is transmitted from the scalp electrodes to a differential amplifier in order to amplify the microscopic potentials severely attenuated by their passage through the skull.

This signal is continuously sampled at a high rate (typically 256 Hz but often more) to provide a high temporal resolution. An analogue band-pass filter is used to filter the raw EEG signal and typically possesses a lower cut-off of 0.5 Hz and a higher cut-off of 50 Hz. The 50 Hz filter helps eliminate electrical noise originating from 50/60 Hz mains power. These filters also affect the processing of nearby frequencies so care must be taken to ensure the cut-off frequencies do not lie too close to the frequencies under investigation. The default cut-offs pose no problems in the sports sciences as the low to mid range frequencies (e.g. 4–20 Hz) are nor mally those of interest.

After amplification and filtering, the EEG signal is (in modern digital systems) relayed to a computer where it can be processed as continuous data and, if desired, its spectral parameters compared with some criterion measure. This is the approach adopted by EEG-biofeedback training in sports and other performance domains which rewards desirable changes in specific frequency bands.

An alternative approach is the study of event-related potentials (ERPs). These usually consist of data epochs of short duration reflecting the cortical response to an external stimulus. In order to offset data noise, many ERPs (often hundreds) are averaged to provide a favourable signal-to-noise ratio.

The typically wave like appearance of the EEG signal reflects the rhythmic activity of underlying synaptic processes. This rhythmicity is thought to reflect the synchronised activity of large neuronal assemblies possibly driven by thalamic pace-maker cells [3]; although the simplicity of this interpretation has been questioned [4]. Anatomically distinct cortical areas produce a variety of different rhythms which are observed as a composite EEG signal. Fourier spectral analysis is typically used to decompose this signal into its constituent frequency bands and to compute the amplitude of each band. These bands have been historically categorised as delta (<4 Hz), theta (4–8 Hz), alpha (8–12 Hz) and beta (13–30 Hz), although alternative classifications have also been employed [5] (See Fig. 2). Slower waves such as delta are typically associated with sleep while faster beta waves are associated with wakefulness and mental activity. Alpha has been linked to a 'relaxed focus or mental readiness'. An increase in alpha activity is often the goal of EEG-biofeedback training aiming to improve sporting performance [6] through increasing the user's ability to remain focused thereby filtering out distracting stimuli, thoughts or emotions. In addition to spectral analysis, more complex analytical techniques have been developed including source localisation methods such as low resolution electro-magnetic tomography, or LORETA [7], which aim to identify the original sources of cortical oscillations. Such methods are described later in this paper.

FIGURE 1: SCANNING ELECTRON MICROSCOPE IMAGE OF A NEURON.
COPYRIGHT © 2003 NICOLAS P. ROUGIER
RELEASED UNDER THE GNU GENERAL PUBLIC LICENSE

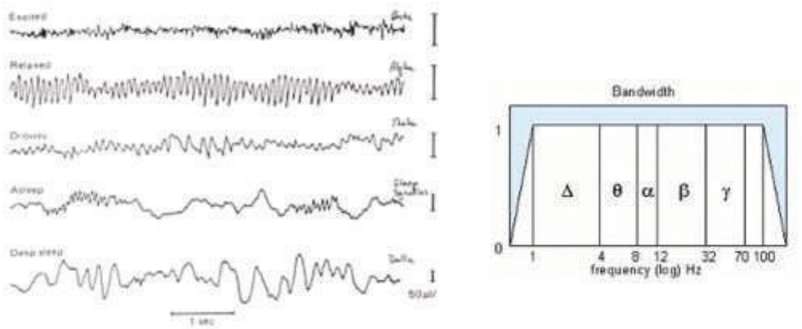


FIGURE 2: THE SUBDIVISION OF EEG SIGNALS

RECORDING METHODS

EEG measurement entails the attachment of electrodes to standardised locations on the scalp. These electrodes are generally made of highly conductive silver or silver chloride (Ag/AgCl) although other metals such as tin, gold and platinum are also used.

Non-metallic material such as carbon fibre can also be employed to allow compatibility with other neuroimaging devices such as MRI. Electrodes are attached to the skin using conductive paste with impedances generally kept below 5 kΩ.

Prior to attaching the electrodes the skin is usually prepared with an abrasive paste to reduce skin impedance [8,9]. The number of active electrodes can range from one, which is sufficient for neurofeedback training, to 20 in the standard procedure, and up to 128 or 256 for source localisation. Electrode placement is standardised to aid interpretability from one laboratory to another. The standard method of electrode placement is the international "10–20 system" [3] depicted in Fig. 3.

A differential amplifier measures the voltage difference between inputs from the active and reference electrodes, with the resulting signal amplified and displayed as a channel of EEG activity. A signal that is common to both inputs is thus automatically rejected in what is known as common mode rejection (CMR). 'Noise' shared across electrodes is thus effectively eliminated leaving only the (hopefully neural) activity specific to the active electrode. In sporting applications, the reference tends to be from electrodes placed on the mastoid (the bone behind the ear), in rarer cases the ear lobes or the average of all (common average montage) or surrounding (Laplacian montage) electrodes in multi-channel setups. (See fig. 3 and 6).

APPLICATIONS OF EEG METHODS IN SPORTS RESEARCH

Given the difficulties of recording EEG during movement, researchers have perhaps unsurprisingly explored alternative ways to apply EEG methodologies in the sports sciences. One approach is to record EEG outside of the execution of the sporting task itself, in order to assess long term clinical outcomes associated with injuries sustained by athletes or to understand pre-task cortical processes. The use of 'imagined' sporting actions as a convenient proxy for real sporting activity is an additional favoured approach. In some cases it is also possible to record EEG during the actual critical movement phase, as in simulated diving conditions or the use of stationary cycling equipment where electrical interference is kept to an acceptable minimum. The following will provide a brief review of studies employing these approaches.

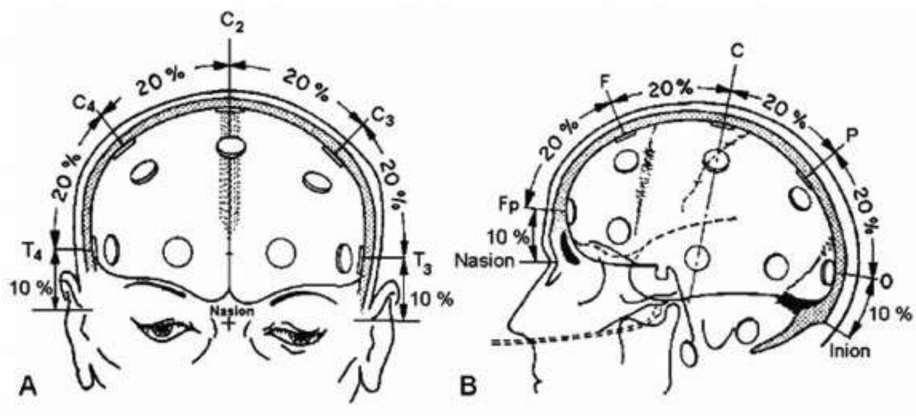


FIGURE 3: Position of electrodes according to International 10-20 System

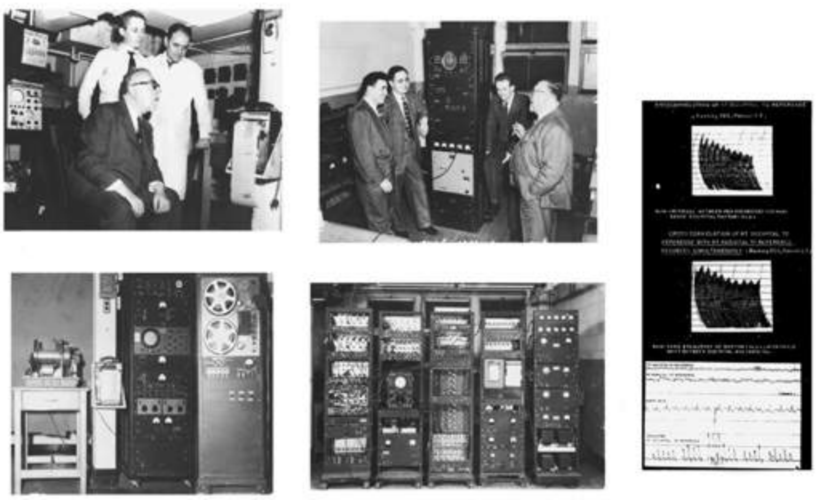


FIGURE 4: Archive images of EEG data processing at the MIT. Copyright © MIT Research Laboratory of Electronics and MIT Museum

PRE/POST MEASUREMENT OF EEG

The first reported use of EEG methods in sports science surfaced in the early 1950's with investigations into boxing [10,11]. Researchers in this field have introduced two distinct themes. Firstly that of studying pre-post combat differences in electro–cortical activity, and secondly examining the differences between healthy adults and professional boxers subjected to repeated head injury over the long-term. Due to the evidence linking EEG findings with symptoms of brain damage, the case has been made for changes to boxing rules, conditions, and health screening [12].Arelated line of inquiry has assessed long term outcomes for footballers following repeated minor head trauma caused by contact between the head and the ball [13,14].

The authors of these studies explored associations between self-reported symptoms such as headaches, dizziness, irritability, memory impairment and neck pain, and abnormal patterns of EEG activity. The findings have come under some criticism on methodological grounds [15], and as such provide only suggestive evidence that EEG methods can be used to signify brain injury in football.
With respect to the study of pre-task cognitive activity, the process of taking aim in target shooting sports presents ideal conditions for EEG recording, as it features a period of motionlessness whilst the target is being attended to prior to firing. This pause in movement has provided researchers with sufficient scope to describe optimal patterns of cortical activity for taking aim in several sports: archery [16,17], golf [18,19] and rifle shooting [20–22] (See. Fig. 7).

Applications in this setting have been able to define predictors of optimal performance in two ways, in differences between expert and non-expert performance, and in pre-shot EEG differences between successful and unsuccessful shots.

This is a salient point as it provides the basis for EEG analysis (real time or post hoc) to be incorporated into athletic training, as means of cognitive augmentation, indicating relationship between the athlete's current state of cortical activation and the established criterion for optimal performance.

IMAGINED MOVEMENT

Another way in which the inaccessibility of EEG during movement measures has been addressed by researchers is to trigger neural activity in the motor cortex by means of imagined movement. This is considered perhaps the least ecologically valid means by which to work within the constraints of EEG recording in the context of physical action as, of the methods described so far, itis the most far removed from the process itself. Nonetheless, motor imagery such as imagined 100 m swimming [23] or imagined training competition [24] produces some differential effects on alpha band EEG signatures as left occipital and pre-central areas or overall mean alpha frequency calculations, respectively. In recent years, Brain Computer Interface applications have interpreted imagined walking and stopping, as recorded from the motor cortex [25], as controllers for navigation around virtual environments. (See Fig. 8). At this stage however, the inferences drawn from the EEG signal develop very rudimentary movement switches that barely begin to approach the complexity and diversity with which actions typically encountered in sports are observed (26).

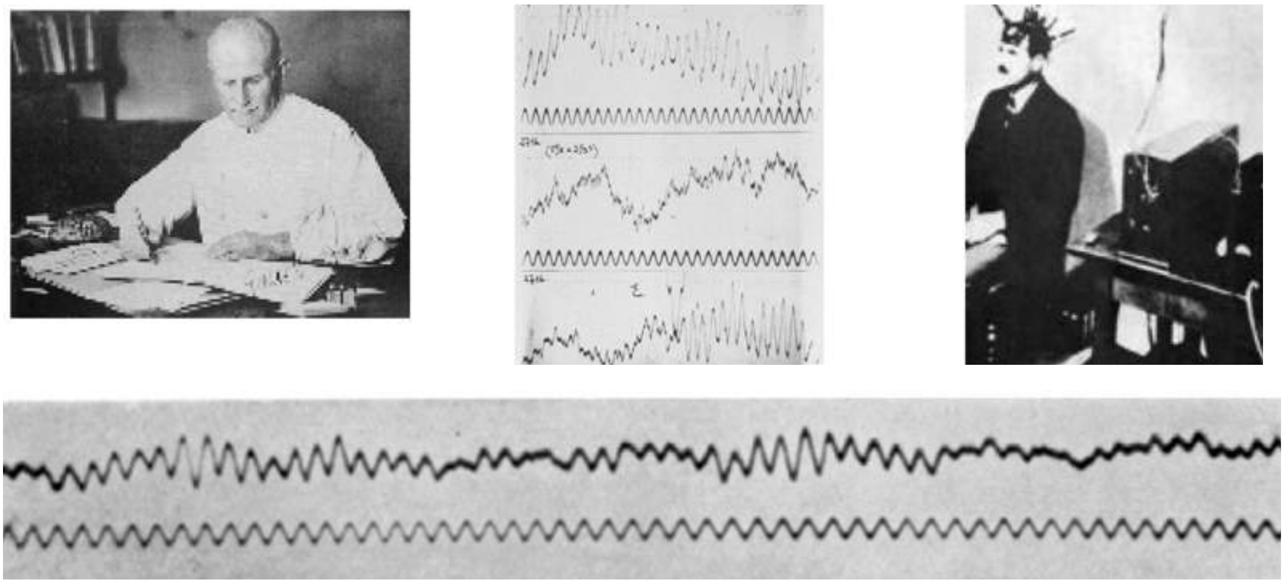


FIGURE 5: HANS BERGER (NEUSS, 21 MAY 1873 - JENA, 1 JUNE 1941) WAS A GERMAN DOCTOR. HE IS KNOWN TO HAVE PERFORMED THE FIRST RECORDING OF BRAIN WAVES AND FOR HAVING INVENTED THE ELECTROENCEPHALOGRAM. BERGER WAS THE FIRST NEUROSCIENTIST TO DESCRIBE THE DIFFERENT WAVES PRESENT IN THE BRAIN, SUCH AS ALPHA WAVES (7-13 HZ), ALSO KNOWN AS "BERGER WAVES".

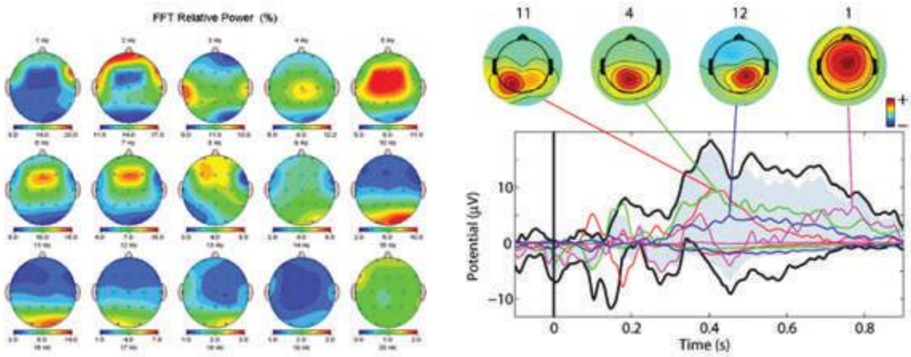


FIGURE 6: EXAMPLES OF TOPOGRAHPICAL ANALYSIS OF EEG SIGNALS

SIMULATED SPORTING ENVIRONMENTS

EEG methods have been used to study impairments to cortical function associated with the environmental conditions in which some sporting activities take place. In diving, High Pressure Nervous Syndrome is characterised by symptoms such as intention tremor, ataxia, motor weakness, sensory symptoms, vertigo, nausea and reduced memory [27]. EEG studies have explored the neural correlates of these symptoms by obtaining reliable measurements through the use of simulated high pressure environments, making it possible to obtain accurate measurements in the conditions being examined [27–29]. The effects of high altitude on mountaineers have also been investigated by means of EEG methods when exploring associations with the symptoms of Acute Mountain Sickness (AMS) such as dizziness, headache, confusion and cerebral edema. Resting EEG measurements were made at base camp and high altitude levels, and have established EEG predictors of AMS as symptoms develop from sub-clinical into clinical [30].

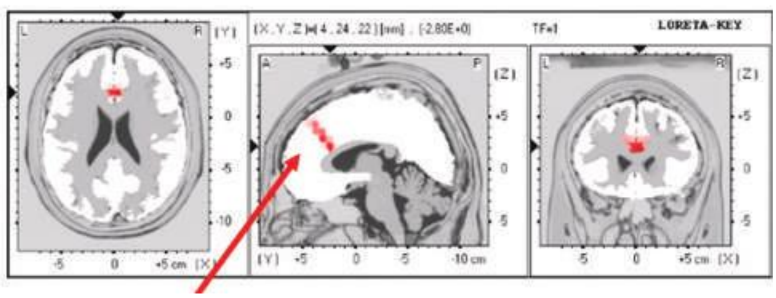
EEG has also been used to assess the sleep problems experienced at high altitudes, diagnosing reduction in stage 4 sleep in comparison with sea level measures [31]. Medication for assisting sleep at high altitude has been validated using EEG recordings to increase sleep quality by increasing slow wave sleep and stage 4 sleep in comparison with placebo controls [32].

EEG RECORDINGS OF IN-TASK CORTICAL ACTIVITY

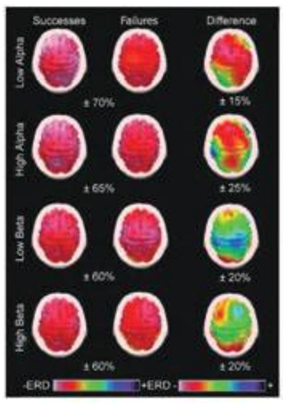
The use of cycle ergometers has afforded a favourable enough signal to noise ratio to enable measures of electro-cortical responses to physical exercise whilst it is taking place. This affordance stems from the minimal head movement resulting from the stability of the equipment. Although some studies have indicated reduced cortical arousal during exercise, others have demonstrated increased arousal. Short-term exercise of moderate intensity has, for example, resulted in reduced activation in the prefrontal cortex [33] and decreased cognitive performance [34]. In other studies, however, exercise has resulted in increased cortical activation, with increases observed in the P300[2] amplitudes suggestive of a facilitation of cognitive processing [35–37].

The apparent discrepancies across the findings of such studies may be attributable to variation in methodological factors such as the intensity and duration of the exercise as well as the physical fitness of the participants [38].

A:



B:



2 - P300 (or abbreviated P3), is an ERP wave (event-related potential) produced by relevant infrequent stimuli. It is considered an endogenous potential because its presence is not registered due to a physical attribute of the stimulus (shape, color, etc ...) but due to the reaction of a person to the stimulus. In particular, P300 is involved in a process that involves the evaluation and categorization of a stimulus. When recorded with the EEG it appears as a positive deflection (negative voltage), with a latency between 300 and 600 ms. The signal is usually more powerful in the parietal lobe. Its presence, magnitude, topography and latency are often used as a measure of brain function in decision-making tasks. While the neural substrates of this ERP still remain unclear, the reproducibility of this signal makes it a common choice for both clinical and laboratory psychological tests.

FIGURE 7: A) A comparison of the theta activity over time prior to the shot (rifle shooting) reveals significant differences between experts and novices. These data indicate a more pronounced Fm (red) in experts; M. Doppelmayra, T. Finkenzellerb, P. Sausenga; Frontal midline theta in the pre-shot phase of rifle shooting: Differences between experts and novices M. Neuropsychology, Volume 46, Issue 5, 2008, Pages 1463–1467
B) Topographical map for low and high frequency of alpha and beta bands in case of success and failure in golf putts; C. Babiloni, C. Del Percio, M. Iacoboni, F. Infarinato, R. Lizio, M. Pirritano, M. Gallamini, N. Marzano, G. Crespi, F. Dassu, F. Eusebi; Golf putt outcomes are predicted by sensorimotor cerebral EEG rhythms; J Physiol 586.1 (2008) pp. 131–139

FIGURE 8: IMAGE OF A PARTICIPANT IN AN EXPERIMENT USING EEG ANALYSIS DURING SIMULATED MOVEMENT. THE PARTICIPANT HAS THE ILLUSION OF WALKING IN A STREET; IN REALITY, THE SUBJECT IS SITTING IN A CHAIR (G. PFURTSCHELLER, R. LEEB, C. KEINRATH, D. FRIEDMAN, C. NEUPER, C. GUGER, M. SLATER; WALKING FROM THOUGHT; BRAIN RESEARCH 1071 (2006) 144-152).

ARTIFACT REDUCTION: PRACTICAL AND TECHNICAL APPROACHES

A substantial problem in EEG is obtaining 'clean' data on cerebral activity, in other words, uncontaminated by non-cerebral artifacts. Physiologic artifacts (e.g. muscular activity and eye blinks) are generated from the body, while extraphysiologic artifacts (e.g. environmental electrical noise) originate from sources outside the body [39]. Physiologic artifacts tend to be a particular problem when recording EEG from a subject who is in motion. This may account for why studies of EEG in sports have generally been confined to disciplines involving relatively minimal head movement such as golf, stationary bike cycling, archery and rifle shooting. Nevertheless, two complementary approaches exist that can substantially reduce or eliminate artifacts.

The first involves minimising movement artifacts during the recording itself. The second requires subsequent signal processing of the data via computational methods to remove artifacts.

The following section will consider some of the artifacts especially pertinent to the sports sciences, how to identify such artifacts, and methods to minimise their occurrence (for the topic of EEG artifacts in general the interested reader is referred to a number of good sources [3,40–42]). Computational methods for artifact removal will be considered in the subsequent section.

MUSCLE ARTIFACTS

Muscular contraction elicits myogenic potentials that can represent a major source of EEG artifact. Sports that involve frequent and intense muscular contraction thus tend to elicit a high degree of electromyographic (EMG) artifact. EMG can exhibit an amplitude of around 100–1000 V, considerably greater than that of EEG (around 10–100 V).

Consequently, muscular activity can obscure neural potentials altogether. This has historically been a problem with ambulatory monitoring of EEG in epilepsy, where EMG spikes can obscure the detection of epileptic spikes [44]. Similarly, the fact that muscle artifact can completely obscure EEG activity can potentially limit EEG applications in the sporting domain.

What can be done about EMG artifact? Fortunately, it is usually easy to distinguish between substantial EMG and EEG from the raw signal morphology, spectral distribution, and scalp location. EMG consists of a series of spiked discharges from underlying motor

units. The frequency of the discharges can range from 20 to 1000 Hz, depending on how many muscle fibres are recruited and the degree of muscular contraction [43]. However, the dominant energy is in the 50–150 Hz band. In contrast, more than 90% of the EEG's spectral power lies within 1–30 Hz frequency. If the brain activity of interest lies below 15 Hz, simple use of low-pass filtering and/or avoiding the directly contaminated electrodes may facilitate adequate signal detection. Muscle artifact also tends to occur in specific places and these should be examined. Scalp locations most affected are the temporal areas T3 and T4 which lie in close proximity to the temporalis muscle. Artifact here thus

tends to reflect jaw movement or tension. This is illustrated in Fig. 9 with irregular activity at T3 with increased power indicated at this location on the topographical scalp map. Jaw tension is a particularly common muscle artifact and, if present, it may be productive to show the subject the effects of muscle movement and tension on the EEG prior to recording and allowing them to learn to reduce their impact. Chewing should also be discouraged.

Additionally, frontal sites Fp1, Fp2, F7 and F8 lie in the region of activity of the frontalis muscle (the 'frowning' muscle) of the forehead. Activity in this region in illustrated in the topographical map of Fig. 10, which also reveals possible neck tension emanating from activity in posterior leads O1 and O2. In addition, the spectral map indicates that peak amplitude at F3 occurs at a high frequency of around 28 Hz. A common way of eliminating overt EMG artifacts is to simply reject the contaminated portions of the EEG. However, when the degree of contamination is considerable, as can be the case when physical exertion is high, rejection can result in a considerable loss of hard-earned data; perhaps leaving too little for meaningful analysis. In this instance, more advanced post processing methods such as Independent Components Analysis (ICA) can be attempted to separate the EMG signal from the raw EEG signal. ICA has shown some promise in isolating muscle artifact; this and other methods are described in detail in section 5.

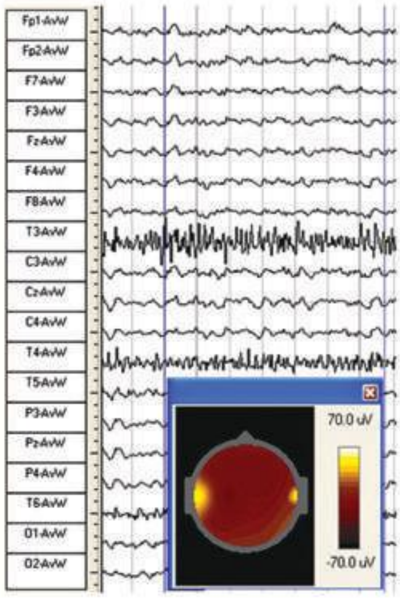


FIGURE 9: EEG SIGNAL AND TOPOGRAPHICAL MAP INDICATE JAW TENSION.

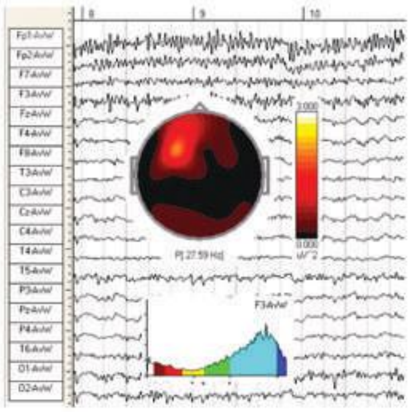


FIGURE 10: EEG TOPOGRAPHICAL MAP AND SPETRAL ANALYSIS INDICATE POSSIBLE FROWNING AND NECK TENSION

SKIN ARTIFACT

Sodium chloride and lactic acid from sweat glands in the scalp can react with the metal of the electrode to alter impedance and thus signal amplitude. If this occurs differentially across active and reference electrodes an impedance mismatch naturally results which can result in large baseline sways (45). Sports that involve sustained physical exertion are naturally more likely to cause sweating and produce these types of artifacts. This problem can be exaggerated with the use of EEG caps or in bald subjects with no hair to help absorb the sweat. Such artifacts are generally recognised by very low frequencies of below 1 Hz and are thus are often easily distinguishable from the mid-range frequencies usually of interest in sports research. Nevertheless, it is good practice to try to reduce the influence of these artifacts at source. Generally, any steps that are likely to lower body temperature are likely to minimise their appearance. The use of a cool air-conditioned room, where possible, and the avoidance of excessive layers of clothing may help. Where feasible, frequent breaks may also help to keep body temperature low. For similar reasons, if one is recording swimmers outside a pool it is important to make sure their hair

is properly dried. All EEG amplifiers should be electrically isolated or wirelessly remote from any mains source of electricity, so not to represent an electrical safety hazard in a wet environment. EEG amplifiers use CMR to reject signals common across inputs. However, impedance mismatches between electrodes can result in a common signal (such as 50 Hz noise) producing different voltages across amplifier inputs. This mis-

N° 13 / May-August 2019

match can result in a distortion of the EEG signal (see Freye [46] for a good account of how the size of the mismatch is related to the magnitude of the signal distortion). It is important therefore to monitor impedances to ensure that differences across active and reference sources are minimal, ideally by ensuring all impedances are kept as low as possible.

ELECTRODE MOVEMENT

Any movement which disturbs the contact of the electrode with the scalp can result in a sudden increase in electrode impedance [3] resulting in a dramatic change in the EEG signal. Overcoming this issue may be one of the biggest challenges; especially in sports
involving a high degree of motion or where the sporting action of research interest necessitates gross motor movement. While electrode movement is easily detected on the EEG signal, contaminated EEG from frequent movement can produce a great deal of data loss.
Great care must be taken to ensure a consistent low impedance contact with the skin. Standard ear clip electrodes should be sufficient for recording EEG in relatively stationary sports like target shooting. Self-adhesive pre-gel disposable electrodes that stick to the mastoid (and in bald subjects to the scalp) can be quickly and easily administered and are less likely to come loose in more active sports (see Freye [46] for a well-illustrated description of electrode types). A more secure method is to glue the electrodes firmly to the scalp with an adhesive conductive gel. Epilepsy/sleep labs have traditionally used collodion, a commonly used one being EC2 Grass-Telefactor paste [47]. It should be pointed out that this method of adhesion is also more cumbersome and disliked by the subjects because of the residue left on the scalp, even after removal of the collodion with acetone [48]. A constant pressure on the electrodes is necessary to prevent them from moving horizontally or vertically. This can be aided with the use of a tight electrode cap, or an elastic gauze or head net when the number of electrodes is relatively low. A Lycra cap can be fitted and aligned with minimal effort, with a 19 channel cap taking around 10–15 min to apply. Securing the leads may minimise the gravitational and rotational forces pulling on the electrodes.

Active electrodes where a pre-amp stage is mounted directly to the electrode on the scalp and magnifies the signal before sending it to the main amplifier, can greatly reduce cable movement artifacts and improve the signal quality in all sports activity and are strongly recommended. Amplifiers with high input impedances can reduce the amount of skin preparation needed whilst maintaining the signal quality [45]. Current development of micro-spiked electrodes [49], that can avoid pressure-induced skin potential changes caused by electrode motion or skin stretching, and super high impedances microchip mounted dry electrodes may hold the promise of a more stable EEG signal in the near future.

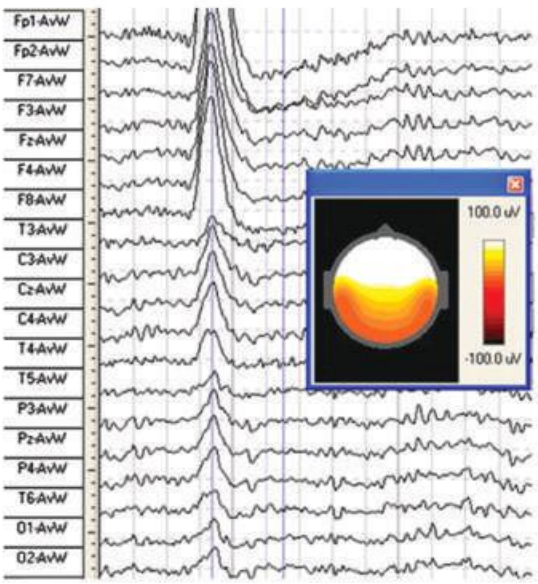


FIGURE 11: EEG AND TOPOGRAPHICAL MAP INDICATE EYE BLINK

FIGURE 12: EXAMPLES OF WIRELESS EEG SYSTEMS CAPABLE OF FEEDING OFF BODY HEAT AND LIGHT.

EYE MOVEMENT

Eye movement is a universal source of artifact and can be precipitated by both eye blinks and lateral eye movements. The potential difference between the cornea and retina is larger than that of cortical potentials [50]. During an eye-blink the eyeball turns upwards. This tends to primarily affect the frontal electrodes, with a large positive deflection seen at Fp1 and Fp2 with a peak amplitude of around 50–200 V lasting 200–400 ms. If the peak is particularly large other electrodes can also be affected. Lateral eye movement is recognisable in the fronto–temporal areas as sharply contoured potentials that are out of phase [3]. Some research has indicated that eye blink rate may not increase during physical exertion [51,52], and therefore this type of artifact may not be any more prevalent during high activity sports. In fact, there is some evidence that increased visual load decreases the rate of eye blinks [53–55]. These types of artifacts may therefore not be any more common in the large number of sports where visual processing demands are high.

The eye blink is easily recognised in the EEG as its raw signal morphology and amplitude have a distinctive pattern, contaminating delta (1–4 Hz) and theta (4–8 Hz) bands predominantly at frontal sites as can be seen in Fig. 11.

Modern blind source separation techniques such as ICA can ameliorate many of the problems caused by eye blinks. It is often wise to record a short test artifact baseline (where the subject attempts to produce various artifacts) to assist in their later identification, by asking the subject to blink their eyes a few times, as well as clenching their jaw and tensing their neck.

ECG ARTIFACT

The electrical activity of the heart is measured by the electro-cardiogram (ECG or EKG). The electrical field from each cardiac pulse is very large and can be measured up to a metre away from the body. ECG is more likely to be seen in people with wide necks (such as weightlifters) but it generally does not pose a problem as it tends only to contaminate the low frequencies of around 1–2 Hz.

This artifact can be common in channels connected to the ears. Most EEG amplifiers reserve an input for ECG recording, ensuring this artifact is easily recognised. The rhythmic and distinct morphology of ECG also means that it is generally easily removed using the post-processing computational methods discussed in the next section.

RESPIRATION ARTIFACT

Respiration artifact arises from the rhythmic body movement of inhalation and exhalation and may be initially observed as high amplitude deflections with a delta wave like frequency. This frequency may be expected to increase depending on the aerobic demands of the sport and the fitness of the athlete.

As with ECG, one channel can be devoted to respiratory movements which can be measured by a stretch sensitive device worn around the chest or abdomen. These types of artifacts are highly suitable for removal by post-processing methods.

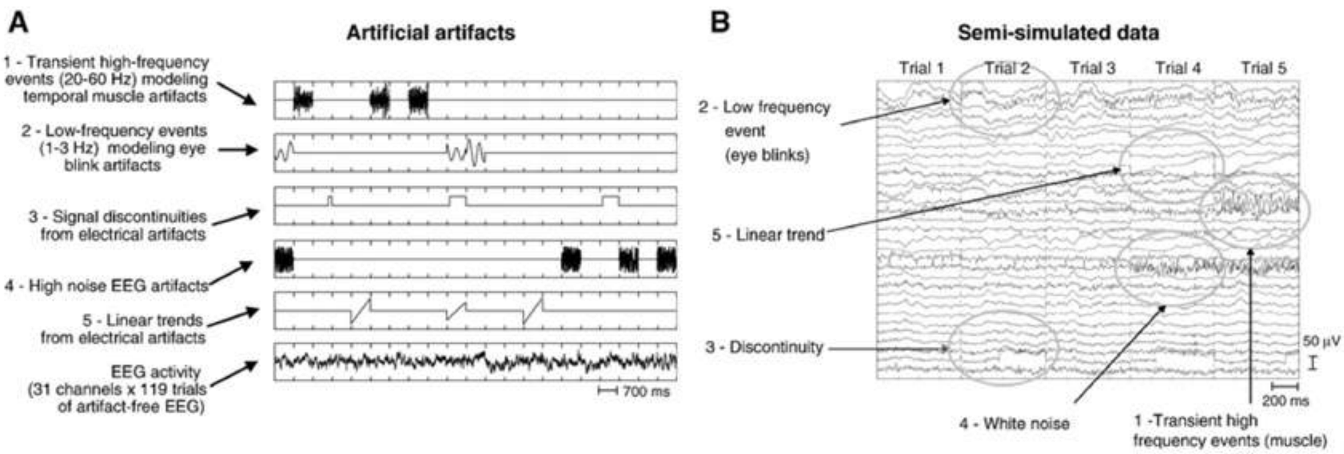


FIGURE 13: A) Different types of simulated artefacts in EEG data periods.
B) simulated data added to real EEG data. (A. Delorme, T. Sejnowski, S. Makeig Enhanced detection of artifacts in EEG data using higher-order statistics and independent component analysis; NeuroImage 34 (2007) 1443 - 1449

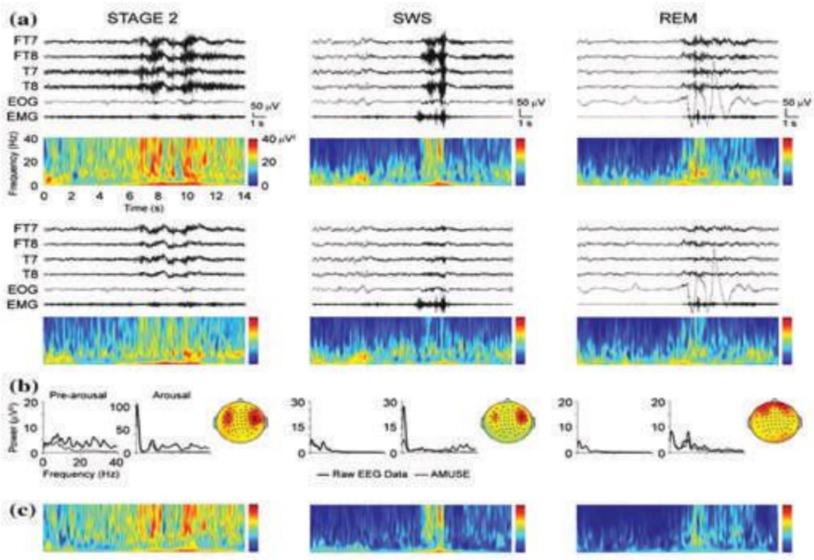


FIGURE 14: EXAMPLE OF REMOVAL OF MUSCLE ARTIFACTS FROM THE RAW EEG SIGNAL (A) RECORDED DURING SLEEP. (M. CRESPO GARCIA, M. ATIENZA, J. L. CANTERO MUSCLE ARTIFACT REMOVAL FROM HUMAN SLEEP EEG BY USING INDEPENDENT COMPONENT ANALYSIS; ANNALS OF BIOMEDICAL ENGINEERING, VOL. 36, NO. 3, MARCH 2008 PP. 467–475)

TONGUE MOVEMENT

Glossokinetic artifacts are created by the potential difference between the tip and base of the tongue and give rise to slow potentials. This type of artifact usually does not occur frequently enough for its removal to cause a significant loss of data.

Furthermore, unless systematically co-occurring with the sporting action under study, glossokinetic artifacts may be good candidates for removal by post-hoc computational methods.

ELECTRICAL INTERFERENCE

Electrical noise from the environment is normally eliminated by common mode rejection as previously described. However, if a large discrepancy exists in the impedance (quality of connection) between electrodes, noise will not appear common to both electrodes and will not be successfully excluded. Electrical noise artifact is most notable at the 50 Hz frequency (Europe) or 60 Hz in the US. Ensuring a robust and good quality connection and checking impedance online may help to minimise this artifact. To reduce electrical noise, active shielding can be used, where a signal is passed down the outer shielding layer of the cable to block any external electromagnetic interference. This may be of use in a hostile electrical environment such as within a Formula One racing car. Wireless equipment greatly limits the presence of data artifacts from electric current; furthermore it is possible to carry out a low pass filter at 50 Hz or a NOTCH filter for the 50 or 60 Hz frequencies during post-acquisition analysis.

RESTRICTION OF MOBILITY

Although not an artifact as such, one of the major problems in neuroimaging in active sports is the enforced restriction of motor movement. Fuelled by recent hardware advances, this is the area in which EEG exhibits substantial advantages compared to other neuroimaging technologies. EEG equipment is comparatively cheap, portable and light, and offers the real possibility of measuring neural activity in a real live sporting environment outside of the laboratory.

Portable amplifiers can record multi-channel EEG directly onto a removable flash card for up to 48 h [56] which can later be transferred to the PC for analysis, eliminating the need for cables. These amplifiers can simultaneously record EMG, ECG, EOC, HR, RSP (respiration) and GSR (Galvanic skin response).

Developments in wireless technology have also seen the introduction of battery-powered amplifiers capable of transmitting EEG information to a PC or pocket PC in real time [57], allowing for the possibility of EEG-biofeedback during sports training. A 4-channel wireless amplifier can weigh less than 200 g and can be strapped to the small of the back with the cables secured to the head with a sweat band. This can allow the subject relatively unrestricted movement within a radius of around 30 m.

With simultaneous recording of sound it is possible to correlate the event (sports action) with the neural response. As described earlier, remotely transmitting electrodes with active chips are currently under development, and hold great promise for the future in entirely eliminating the need for cables. Battery free systems powered by body heat and ambient light are also currently under development (58). (Fig. 12).

ARTIFACT REMOVAL: COMPUTATIONAL METHODS

The previous section described ways to minimise movement artifacts present in the recording itself. A second, complementary approach involves separating neural signals and artifacts by post-processing of the data through computational methods. The choice of post hoc data analysis initially depends on the signal dimensions (as well as the number of channels).Multi-channel data carries more information; hence it is statistically more robust and thus more reliable. However more channels means more data, so blind source separation techniques that, by definition, require multiple channels (such as ICA) involve more extensive experimental setup, as well as a higher computational load; a factor that usually limits them to offline processing. A potential workaround is to have only one or a few electrodes of the region(s) of interest, and concentrate on regions and/or frequencies that are less susceptible to artifact. For example, the central sensorimotor regions are located furthest away from cranial muscles and are also less affected by eye-blink artifacts than frontal regions. Basic digital filtering (e.g. finite impulse response) may also be useful in isolating particular frequencies of interest that are more robust to artifact, such as high theta and alpha (6–13 Hz) which are least affected by both low frequency (movement, blinks and sweat) and high frequency (muscle and electrical noise) artifacts. Another alternative is to apply autoregressive frequency analysis (such as the Yule-Walker algorithm [59]), which is reported to be more stable under movement and noise artifacts than conventional Fourier-based methods, which are prone to spectral leakage and poor performance under conditions of low signal levels (10's of V) and can result in a low signal-to-noise ratio.

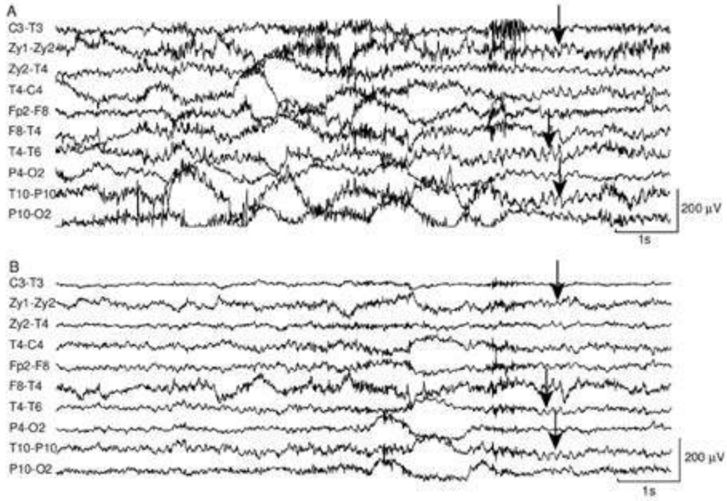


FIGURE 15: A) EEG SIGNAL IN WHICH DIFFERENT MOVEMENT ARTEFACTS AND SOME EMG ACTIVITIES APPEAR.
B) THE SIGNAL WAS AUTOMATICALLY FILTERED TO ATTENUATE ARTIFACTS, BUT THE LOSS OF BRAIN ACTIVITY IS ALSO EVIDENT. THE ARROWS INDICATE THE POINTS WHERE THE EEG ACTIVITY HAS BEEN SIGNIFICANTLY ATTENUATED AFTER PROCESSING.
(P. LEVAN, E. URRESTARAZU, J. GOTMAN; A SYSTEM FOR AUTOMATIC ARTIFACT REMOVAL IN ICTAL SCALP EEG BASED ON INDEPENDENT COMPONENT ANALYSIS AND BAYESIAN CLASSIFICATION; CLINICAL NEUROPHYSIOLOGY 117 (2006) 912–927)

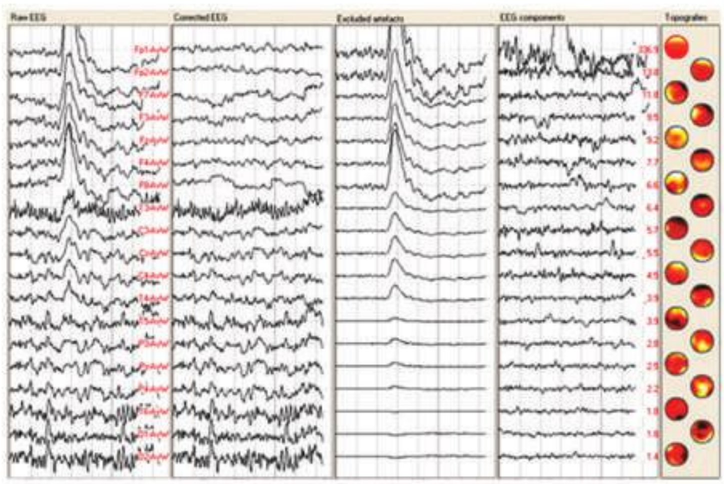


FIGURE 16: REMOVAL OF ARTIFACTS DUE TO THE MOVEMENT OF THE EYELID. USING ICA. THE COLUMNS SHOW FROM LEFT TO RIGHT: THE RAW SIGNAL, THE CORRECT SIGNAL, THE EXCLUDED ARTIFACTS, THE TOPOGRAPHIC COMPONENTS OF THE SIGNAL.

Nevertheless, perhaps the greatest modern advance in artifacting (and signal processing in general) has occurred with the advent of independent component analysis, or ICA, pioneered by Bell and Sejnowski in 1995 [60]. To the best knowledge of the authors, there is still surprisingly little if any published research on the use of ICA to remove large artifacts due to motion during sport or physical exercise. Its most recently reported application in respect has been in correcting task-related movement during fMRI prompted by the extreme sensitivity of this method of neuroimaging to movement [61]. Nevertheless, ICA does offer great promise as a technique for artifact removal in exercise research. ICA is a higher or-

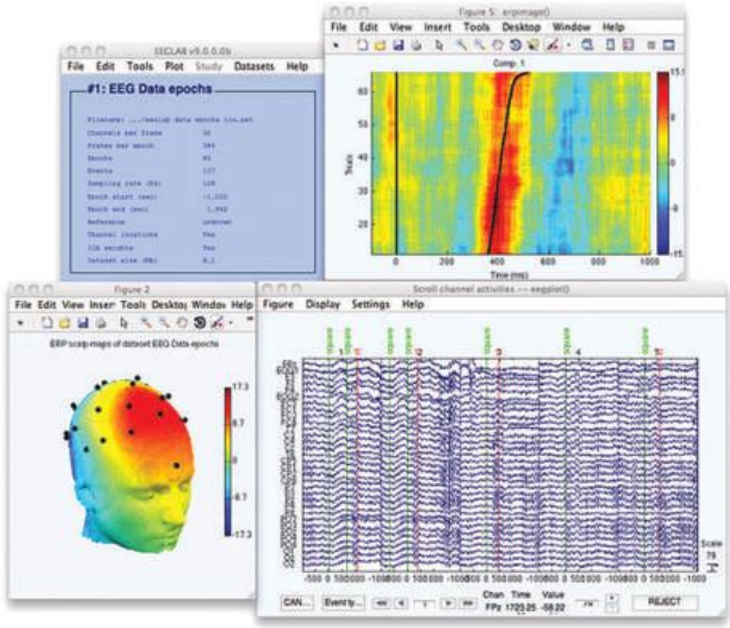


FIGURE 17: EXAMPLE OF AN EEGLAB SESSION UNDER LINUX. (A. DELORME, S. MAKEIG; EEGLAB: AN OPEN SOURCE TOOLBOX FOR ANALYSIS OF SINGLE-TRIAL EEG DYNAMICS. JOURNAL OF NEUROSCIENCE METHODS, 2004, 134: 9-21)

der statistical method developed to extract individual signals (referred to as components) from mixtures of signals, based on the assumption that different physical processes (referred to as sources) will generate unrelated signals. One methodological caveat is that since the aim of ICA is to separate underlying 'source' signals considered to be 'statistically independent' over time, it requires a relatively large amount of data in both length (EEG samples) as well as channels (the number of sources it yields is directly restricted by the number of recording electrodes used [62]). Even on modern day computers, common ICA algorithms may take from minutes (for individual EEGs) up to hours (for very long EEG or if analysed en masse) to complete. In addition to the assumption of independence of source origins, common ICA algorithms (e.g. InfoMax, FastICA) operate under two further assumptions. Firstly that the underlying sources must exhibit non-Gaussianity, i.e. they must be non-normally distributed (other techniques do not require this assumption (see [63]), although these are not discussed in detail here). Secondly the sources should be stationary, that is to say, they should each have a fixed location throughout the recording. Recent years have seen a remarkable proliferation of ICA related articles with successful applications described in reference to both artifacting [64] (Fig. 13) and EEG source modelling [65]. Evidence for the former includes artifact removal of muscle [66] (Fig. 14) contamination, eye blinks and movement [67,68], noise [67,68], as well as cardioballistic phenomena [69]. Fig. 16 illustrates how ICA was used to extract an eye blink component from the raw EEG in data we recently recorded from a sample of contemporary dance performers. It should be borne in mind that different ICA algorithms (popular ones include Infomax, SOBI, FastICA and JADE) are likely to best detect specific types of artifacts. The JADE algorithm, for example, may be particularly effective for tackling muscle artifact [66]. Complete artifact elimination may therefore require selection of one or more ICA algorithms. The greatest advantage ICA has over conventional artifacting methods is in the fact that an artifact 'component' can simply be linearly subtracted without theoretically incurring any loss to the remaining EEG data occurring simultaneously with it. The spreading popularity of ICA cannot be mentioned without honouring the Matlab toolbox EEGLAB [70], a freely available open source research software (http://sccn.ucsd.edu/eeglab/), (Fig. 17) and the first to implement ICA (via the Infomax algorithm) for general EEG/ERP analysis and artifacting. A strength of this toolbox is that it also enables the user to identify and cluster matching components (or artifacts) between different subjects based on their scalp map, dipole projection (DIPFIT plugin), spectral power or ERP characteristics. In light of this, and given that ICA typically decomposes spatially fixed and physiologically plausible EEG sources, an effective way to approach artifact-rich data is not to painstakingly remove the artifact cocktail but rather concentrate on extracting the EEG source components themselves.

Ironically, the motivation for removing artifacts is primarily to get a stable record of the underlying independent EEG, yet this is what ICA is already made to do and does best. Thus, isolating and clustering matching EEG components of interest [71] (frontal midline theta, mu rhythm, or parietal alpha for instance) across subjects not only circumvents complicated artifacting but also minimises the variability and error involved when comparing electrophysiological recordings of different individuals and conditions, as there inevitably exist some individual differences in EEG cap placement as well as physical location/orientation of EEG source dipoles. Notwithstanding, ICA presents an apparent trade-off between the dimensionality of the EEG data (i.e. the number of channels) which when greater, yields more components (thus more complex as well as accurate information), and the practicality of experimental setup or the computational load. Part of the purpose of artifacting is to remove disruptive (or uninformative) data that further adds to the complexity of the EEG. For a fixed number of channels however, some of the components are 'wasted' on the artifacts and hence the remaining cerebral components are not resolved as clearly. An effective compromise is to use an intermediate number of channels (e.g. 21 or 31), perform ICA, subtttract the major artifactual components and then run ICA again on the remainder of the data. This conveniently restores the maximum number of available components, without the subtracted artifacts.

FUTURE DIRECTIONS

In the quest for ever-more refined tools to probe the signals of the brain, there is new evidence of work in progress with regards to further improving ICA, with a so-called semi-blind approach [72]. By effectively imposing temporal or spatial constraints on the underlying source mixture via such methods as LIANA [73],or by wavelet enhanced thresholding [74] which more faithfully preserves spectral amplitude and coherence. Other research is centred on so-called automated [75,76] (Fig. 15) artifact removal, which makes use of statistical parameters to automatically classify multiple types of artifacts and remove them without the need for human assistance. Lastly, another promising area which will no doubt prove valuable is online real-time artifact removal, which includes both ICA [77] and faster traditional methods [78]. This could be used to extract artifacts a priori during recording itself, making it especially useful for potential EEG neurofeedback applications in sports enhancement (e.g. training alpha desynchronisation in golf [18]).

NEUROFEEDBACK AND PERFORMANCE ENHANCEMENT

A discussion of EEG methodology in the sports sciences would seem incomplete without some discussion of neurofeedback. Previous research has shown that the EEG of expert sportsmen shows distinct differences relative to non-experts [6,17,79,80]. If a causal link is assumed, neurofeedback offers the potential to provide performance improvements by training an individual's EEG. With conventional neurofeedback, specific components of the EEG spectrum are fed back to the individual in real time using an online feedback loop in the form of either audio or visual information. Visual feedback is often in the form of a moving bar with the amplitude of the selected EEG frequency band represented by the size of the bar, and with the participant aiming to increase or decrease its amplitude as instructed. This may be accompanied by auditory feedback to indicate a point scored. The aim is to train the individual to gain learned control over a particular component of brain activity. Typically a bar representing the chosen frequency band to be enhanced will be increased, while simultaneously higher and lower bands are inhibited and their respective bars reduced in amplitude. The visual feedback may depict a virtual reality performing space to provide ecological validity and transfer learning more effectively to the performance context, as in the case of our current studies of acting performance [81] where the volunteers learn to regulate cortical activity and the illumination in the theatre auditorium is raised or lowered. Despite numerous anecdotal reports attesting to its efficacy [2], there are actually very few well-controlled studies that have directly examined the ability of neurofeedback to produce improvement in measures of sporting performance. In fact, to the authors' knowledge only two studies to date have appeared in peer reviewed journals. Landers et al. [16] set out to determine whether neurofeedback could improve performance in 24 skilled archers. One group received peak performance neurofeedback training with reward provided for low frequency activity in the left hemisphere. The rationale for this type of training is based on EEG studies demonstrating more slow frequency activity in skilled marksmen in the left hemisphere (with the most pronounced differences in the left-centro-temporal-parietal areas [82]). In the Landers study, the neurofeedback group showed significant improvements in shooting accuracy. No performance improvements were observed in an 'incorrect' neurofeedback (low frequency activity in the right hemisphere rewarded) or a control group, with the former in fact showing a significant deterioration in performance. A more recent study by

N° 13 / May-August 2019

Arns et al. [83], examined the effect of neurofeedback vs. no neurofeedback on putting performance in golf. The criteria for frequency band reward in the neurofeedback training were based on each participant's individual EEG profile during successful putts prior to neurofeedback training. The overall percentage of successful putts was significantly greater after neurofeedback was administered. Although there is a lack of studies directly examining the effects of neurofeedback in sport, a number of controlled studies have examined the impact of such training on performance measures outside of the sporting arena. Neurofeedback has elicited positive changes in the domains of memory, attention, creativity and mood [84–87], which has promising implications for peak performance training in sports. Neurofeedback has a long history of use as a clinical application [88–90], although such applications are not discussed here. Probably the largest body of neurofeedback validation studies has been conducted with the aim of enhancing cognitive performance [91]. The underlying rationale for these studies is that a specific cognitive function can be enhanced by training the frequency most closely associated with this function.

Studies of neurofeedback and cognition appear to be primarily devoted to examining the relationship between beta (13–30 Hz) and focused attention, and it is these studies that may have the most relevance to the sporting world. It should be noted that an extensive coverage of such studies is beyond the scope of the current paper, with a more detailed review provided by a number of good sources [6,91,92]. Fast wave training components of sustained attention, such as omission versus commission errors, have found to be differentially influenced by adjacent bands; e.g. 12–14 Hz termed the sensory motor rhythm band (SMR), and 15–20 Hz referred to as the low beta band [86,93]. In one such study, improvements in sustained attention along with verbal working memory were observed only in the SMR group [84]. The SMR band has been of particular interest where, through the reduction in excitability of the sensory motor cortex, performance is characterised by a sustained and relaxed attentional focus, an enlarged working memory space, and a more modulated performance with greater readiness to respond and a more efficient performance overall [94]. In a preliminary study, trainee eye surgeons receiving SMR training performed more efficiently with less time on task, yet with slightly longer pauses between tasks [95].

Fast wave training may be contrasted with slow wave training with eyes closed where auditory feedback is contingent on production of theta (4–8 Hz) and alpha activity (8–12 Hz). The aim is to increase the theta to alpha ratio by making the sound associated with theta particularly conducive to relaxation (e.g. the sound of waves breaking on the shore). About two thirds of individuals begin with alpha higher than theta, and to set the relaxation process in motion alpha may be rewarded with a lower threshold than theta at first. Phasic increase in theta and alpha may also be rewarded with separate sounds such as a resonant gong. Theoretically the aim is to induce relaxation to a state of hypnogogia which has historically been associated with creative insights [96]. Slow wave training has benefited competitive ballroom dance performance in a controlled investigation [97]. Professionally significant improvements were obtained with alpha/theta training in dancers who went on to win the UK university championship. Interestingly, another biofeedback procedure - heart rate coherence training - was equally effective in improving performance overall, with particular impact on technique, whereas slow wave training impacted on timing. Slow wave training has widespread implications. It enhances feelings of confidence, well being and increases energy. In musicians it is particularly effective with the communicative aspects of performance which are underpinned by confidence, and this we have shown even with novice abilities (musicians who sing). Slow wave training has impacted, though, on all aspects of performance including breath control and pitch. However, it may be fast wave training, SMR in particular, that has iimportant applications in sports involving skilled visuomotor activities Overall, EEG-biofeedback shows promise in offering a means of optimising function that may have a sporting application. However, there is a dearth of controlled studies directly investigating this possibility, with further research clearly warranted [98].

CONCLUDING REMARKS

EEG represents a useful methodological tool in understanding cortical processes that underlie performance in sporting and non-sporting domains. Although EEG lacks the spatial resolution of more expensive methods such as MEG or fMRI, it offers excellent temporal resolution and with advances in wireless hardware and equipment portability, allows a freedom of movement almost impossible to achieve with other neuroimaging technologies. Recording EEG during motion does present a number of problems with respect to obtaining 'clean' cerebral data. However, careful attention to proper methodological practices and developments in hardware and computational processing models offer a promising means of minimising, if perhaps not entirely eradicating, these problems.

REFERENCES:

1. D.M. Ahrendt, Am. Fam. Physician 63 (2001) 913–922.
2. D.T. Max, Wired for Victory. Retrieved 13th June 2008. Available from: <http:// www.mensvogue.com/health/articles/2 006/12/18/mindroom>.
3. A.J. Rowan, E. Tolunsky, Primer of EEG, Elsevier, Philadelphia, USA, 2003.
4. P.L. Nunez, R. Srinivasan, in: Electric Fields of the Brain: The Neurophysics of EEG, Oxford University Press, New York, 2006.
5. G. Rippon, in: C. Senior, T. Russell, M.S. Gazzaniga (Eds.), Methods in Mind, MIT Press, MA, 2006, pp. 237– 264.
6. D.J. Vernon, Appl. Psychophysiol. Biofeedback 30 (2005) 347–364.
7. R.D. Pascual-Marqui, C.M. Michel, D. Lehmann, Int. J. Psychophysiol. 18 (1994) 49–65.
8. D.P. Burbank, J.G. Webster, Med. Biol. Eng. Comput. 16 (1978) 31–38.
9. E. Seitsonen, A. Yli-Hankala, K. Korttila, Acta Anaesthesiol. Scand. 44 (2000) 1266–1270.
10. A. Ravina, Presse Med. 60 (1952) 1575.
11. E.W. Busse, A.J. Silverman, J. Am. Med. Assoc. 149 (1952) 1522–1525.
12. M. Kaste, T. Kuurne, J. Vilkki, K. Katevuo, K. Sainio, H. Meurala, Lancet 2 (1982) 1186–1188.
13. A.T. Tysvaer, Sports Med. 14 (1992) 200–213.
14. A.T. Tysvaer, O.V. Storli, Am. J. Sports Med. 17 (1989) 573–578.
15. A. Rutherford, R. Stephens, D. Potter, Neuropsychol. Rev. 13 (2003) 153–179.
16. D.M. Landers, S.J. Petruzzello, W. Salazar, D.J. Crews, K.A. Kubitz, T.L. Gannon, M. Han, Med. Sci. Sports Exerc. 23 (1991) 123–129.
17. W. Salazar, D.M. Landers, S.J. Petruzzello, M. Han, D.J. Crews, K.A. Kubitz, Res. Q. Exerc. Sport 61 (1990) 351–359.
18. C. Babiloni, C. Del Percio, M. Iacoboni, F. Infarinato, R. Lizio, N. Marzano, G. Crespi, F. Dassù, M. Pirritano, M. Gallamini, F. Eusebi, J. Physiol. 586 (2008) 131–139.
19. D.J. Crews, D.M. Landers, Med. Sci. Sports Exerc. 25 (1993) 116–126.
20. M. Doppelmayr, T. Finkenzeller, P. Sauseng, Neuropsychologia 46 (2008) 1463–1467.
21. C.H. Hillman, R.J. Apparies, C.M. Janelle, B.D. Hatfield, Biol. Psychol. 52 (2000) 71–83.
22. N. Konttinen, H. Lyytinen, J. Sports Sci. 11 (1993) 257–266.
23. L. Beyer, T. Weiss, E. Hansen, A. Wolf, A. Seidel, Int. J. Psychophysiol. 9 (1990) 75–80.
24. T. Weiss, L. Beyer, E. Hansen, Int. J. Psychophysiol. 11 (1991) 203–205.
25. G. Pfurtscheller, R. Leeb, C. Keinrath, D. Friedman, C. Neuper, C. Guger, M. Slater, Brain Res. 1071 (2006) 145–152.
26. A. Dietrich, Methods 45 (2008) 319–324.
27. J.A. Aarli, R. Vaernes, A.O. Brubakk, H. Nyland, H. Skeidsvoll, S. Tonjum, Acta Neurol. Scand. 71 (1985) 2–10.
28. M.J. Halsey, Physiol. Rev. 62 (1982) 1341–1377.
29. J.A. Kinney, R. Hammond, R. Gelfand, J. Clark, Electroencephalogr. Clin. Neurophysiol. 44 (1978) 157–171.
30. B. Feddersen, H. Ausserer, P. Neupane, F. Thanbichler, A. Depaulis, R. Waanders, S. Noachtar, J. Neurol. 254 (2007) 359–363.
31. T.P. Finnegan, P. Abraham, T.B. Docherty, Electroencephalogr. Clin. Neurophysiol. 60 (1985) 220–224.
32. M. Beaumont, D. Batejat, C. Pierard, P. Van Beers, M. Philippe, D. Leger, G. Savourey, J.C. Jouanin, Sleep 30 (2007) 1527–1533.
33. L. Nybo, B. Nielsen, J. Appl. Physiol. 91 (2001) 2017–2023.
34. M.B. Pontifex, C.H. Hillman, Clin. Neurophysiol. 118 (2007) 570–580.
35. Y. Nakamura, K. Nishimoto, M. Akamatu, M. Takahashi, A. Maruyama, Electromyogr. Clin. Neurophysiol. 39 (1999) 71–74.
36. M.N. Magnie, S. Bermon, F. Martin, M. Madany-Lounis, G. Suisse, W. Muhammad, C. Dolisi, Psychophysiology 37 (2000) 369–377.
37. C.H. Hillman, E.M. Snook, G.J. Jerome, Int. J. Psychophysiol. 48 (2003) 307–314.
38. F. Grego, J.M. Vallier, M. Collardeau, S. Bermon, P. Ferrari, M. Candito, P. Bayer, M.N. Magnie, J. Brisswalter, Neurosci. Lett. 364 (2004) 76–80.
39. S.R. Benbadis, in: T. Lee-Chiong (Ed.), Sleep: A Comprehensive

Handbook, John Wiley & Sons, Colorado, USA, 2005.
40. S.C. Schachter, D.L. Schomer, B.S. Chang, Atlas of Ambulatory EEG, Elsevier, MA, USA, 2005.
41. M. Beaussart, J.D. Guiev, in: A. Redmond (Ed.), Handbook of Electroencephalography and Clinical Neurophysiology, Elsevier, Amsterdam, 1977, pp. 80–96 (11A).
42. M. Saunders, in: D.W. Klass, D.D. Daly (Eds.), Current Practice of Clinical Electroencephalography, Raven Press, NY, 1979, pp. 37–68.
43. J.L. Andreassi, Psychophysiology: Human Behavior and Physiological Response, Lawrence Erlbaum, NJ, 2000.
44. L.P. Panych, J.A. Wada, M.P. Beddoes, Electroencephalogr. Clin. Neurophysiol. 72 (1989) 268–276.
45. T.C. Ferree, P. Luu, G.S. Russell, D.M. Tucker, Clin. Neurophysiol. 112 (2001) 536–544.
46. E. Freye, Cerebral Monitoring in the OR and ICU, Springer, New York, 2005.
47. C. Falco, F. Sebastiano, L. Cacciola, F. Orabona, R. Ponticelli, P. Stirpe, G. Di Gennaro, Clin. Neurophysiol. 116 (2005) 1771–1773.
48. C.D. Binnie, Clinical Neurophysiology, Butterworth, Heinemann, Boston, 1995.
49. M. Matteucci, R. Carabalona, M. Casella, E. Di Fabrizio, F. Gramatica, M. Di Rienzo, E. Snidero, L. Gavioli, M. Sancrotti, Microelectron. Eng. 84 (2007) 1737– 1740.
50. M. Iwasaki, C. Kellinghaus, A.V. Alexopoulos, R.C. Burgess, A.N. Kumar, Y.H. Han, H.O. Luders, R.J. Leigh, Clin. Neurophysiol. 116 (2005) 878–885.
51. J. Tieman, L.J. Peacock, K.J. Cureton, R.K. Dishman, Int. J. Neurosci. 106 (2001) 21–33.
52. J.C. Smith, P.J. O'Connor, Biol. Psychol. 63 (2003) 293–310.
53. F. Lecret, M. Pottier, Le Travail Humain 34 (1971) 51–68.
54. J.A. Stern, J.A. Bynum, Aerosp. Med. 41 (1970) 300–305.
55. J.A. Veltman, A.W.K. Gaillard, Biol. Psychol. 42 (1996) 323–342.
56. M.D. Linderman, V. Gilja, G. Santhanam, A. Afshar, S. Ryu, T.H. Meng, K.V. Shenoy, Conf. Proc. IEEE Eng. Med. Biol. Soc. 1 (2006) 1212– 1215.
57. Mind Media, Flexible 32 Channel Monitoring & QEEG. Retrieved 15th June 2008, Available from: <http://www.mindmedia.nl/english/nex us32.php>.
58. Interuniversity Microelectronics Centre, Wireless EEG system self-powered by body heat and light. Retrieved 15th June 2008. Available from:<http://www.sciencedaily.com/releases/2008/0 4/080412172006.htm>.
59. M.J. Griffiths, P. Grainger, M.V. Cox, A.W. Preece (2005) in "3rd IEE International Seminar on Medical, Applications of Signal Processing".
60. A. Bell, T. Sejnowski, Neural. Comput. 7 (1995) 1129–1159.
61. T. Kochiyama, T. Morita, T. Okada, Y. Yonekura, M. Matsumura, N. Sadato, Neuroimage 25 (2005) 802–814.
62. J.V. Stone, Trends Cogn. Sci. 6 (2002).
63. C.G. Puntonet, A. Prieto, Independent Component Analysis and Blind Signal Separation, Springer, New York, 2004.
64. A. Delorme, T. Sejnowski, S. Makeig, Neuroimage 34 (2007) 1443– 1449.
65. J. Onton, M. Westerfield, J. Townsend, S. Makeig, Neurosci. Biobehav. Rev. 30 (2006) 808–822.
66. M. Crespo-Garcia, M. Atienza, J.L. Cantero, Ann. Biomed. Eng. 36 (2008) 467– 475.
67. R. Romo-Vazquez, R. Ranta, V. Louis-Dorr, D. Maquin, Conf. Proc. IEEE Eng. Med. Biol. Soc. (2007) 5445–5448.
68. W. Zhou, J. Zhou, H. Zhao, L. Ju, Conf. Proc. IEEE Eng. Med. Biol. Soc. 6 (2005) 6017–6020.
69. W. Nakamura, K. Anami, T. Mori, O. Saitoh, A. Cichocki, S. Amari, IEEE Trans. Biomed. Eng. 53 (2006) 1294–1308.
70. A. Delorme, S. Makeig, J. Neurosci. Methods 134 (2004) 9–21.
71. J. Onton, A. Delorme, S. Makeig, Neuroimage 27 (2005) 341–356.
72. C. Hesse, C. James, IEEE Trans. Biomed. Eng. 53 (2006) 2525–2534.
73. N. Hironaga, A.A. Ioannides, Neuroimage 34 (2007) 1519–1534.
74. N.P. Castellanos, V.A. Makarov, J. Neurosci. Methods 158 (2006) 300–312.
75. S. Boudet, L. Peyrodie, P. Gallois, C. Vasseur, Conf. Proc. IEEE Eng. Med. Biol. Soc. 1 (2006) 5719–5722.
76. P. LeVan, E. Urrestarazu, J. Gotman, Clin. Neurophysiol. 117 (2006) 912–927.
77. F. Shayegh, A. Erfanian, Conference Proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference 1 (2006) 5269–5272.
78. N. Mourad, J.P. Reilly, H. De Bruin, G. Hasey, D. MacCrimmon, ICASSP, IEEE International Conference on Acoustics, Speech and Signal Processing— Proceedings, 1, Art. No. 4217099 (2007) I393–I396.
79. E.I. Bird, Int. J. Sports Psychol. 18 (1987) 9–18.
80. S.J. Radlo, G.M. Steinberg, R.M. Singer, D.A. Barba, A. Melinkov, Int. J. Sports Psychol. 33 (2002) 205–217.
81. T. Steffert, A. Steed, J. Leach, T. Thompson, J. Gruzelier, Revista Espanola de Neuropsicologia 10 (2008) 71–77.
82. A.J. Haufler, T.W. Spalding, D.L. Santa Maria, B.D. Hatfield, Biol. Psychol. 53 (2000) 131–160.
83. M. Arns, M. Kleinnijenhuis, K. Fallahpour, R. Breteler, J. Neurother. (in press)..
84. D. Vernon, T. Egner, N. Cooper, T. Compton, C. Neilands, A. Sheri, J. Gruzelier, Int. J. Psychophysiol. 47 (2003) 75–85.
85. T. Egner, J.H. Gruzelier, Neuroreport 14 (2003) 1221–1224.
86. T. Egner, J.H. Gruzelier, Neuroreport 12 (2001) 4155–4159.
87. T. Thompson, T. Steffert, E. Redding, J. Gruzelier, Revista Espanola de Neuropsicologia 10 (2008) 59–62.
88. M.B. Sterman, L.R. Macdonald, R.K. Stone, Epilepsia 15 (1974) 395– 416.
89. J.D. Kropotov, V.A. Grin-Yatsenko, V.A. Ponomarev, L.S. Chutko, E.A. Yakovenko, I.S. Nildshena, Int. J. Psychophysiol. 55 (2005) 23–24.
90. M. Foks, Educ.Child Psychol. 22 (2005) 67–77.
91. W. Klimesch, Brain Res. Brain Res. Rev. 29 (1999) 169–195.
92. D. Vernon, A. Frick, J. Gruzelier, J. Neurother. 8 (2004) 53–82.
93. T. Egner, J.H. Gruzelier, Clin. Neurophysiol. 115 (2004) 131–139.
94. J. Gruzelier, T. Egner, D. Vernon, in: C. Neuper, W. Klimesch (Eds.), Event-Related Dynamics of Brain Oscillations, 159, Elsevier Science, Amsterdam, 2006, pp. 421–431.
95. T. Ros, P. Bloom, L. Benjamin, M. Moselely, L. Parkinson, J. Gruzelier, Revista Espanola Neuropsicol. 10 (2008) 97–101.
96. T. Boynton, J. Neurother. 5 (2001) 5–18.
97. J. Raymond, I. Sajid, L.A. Parkinson, J.H. Gruzelier, Appl. Psychophysiol. Biofeedback 30 (2005) 65–73.
98. D.C. Hammond, J. Am. Board Sport Psychol. (2007) 1–9.

KNOWLEDGE FRONTIERS
THE CONCEPTS OF MECHANO-BIOLOGY APPLIED TO STRENGTH TRAINING

DONATO FORMICOLA, PHD
SUISM University Sport Service Centre, University of Turin

MECHANOBIOLOGY

Mechanobiology is an emerging branch of biological disciplines that avails of the principles of mechanics to explain the vital activities of cells[1]. Thanks to state of the art laboratory instruments, biologists are now able to measure the forces that, coming from the external environment, act on the tissues of the organism and modify its cellular structure. When a microscopic fraction of organic tissue is stretched mechanically, even for a brief moment, the cells of that area react immediately producing new molecules, growing, moving, differentiating, proliferating, degenerating, collapsing or dying. Mechanosensitivity is the ability of a cell to encode a mechanical stimulus such as a mechanical stimulation, or a start signal for a specific biological response, called mechanotransduction, capable of converting the tension that has arrived into a chemical or electrical reaction.

Mechanobiology analyses and codifies the behaviour of cells when they are stressed by external forces. The stimulated cells can act on themselves, on the adjacent ones, or on the connective tissue that surrounds the entire tissue in which they live[2]. With rigid connective tissue, the laminar stresses act directly on the cells[3]. The more the cytoskeleton (the support frame of a cell) is rigid, the greater the resistance with which the cells oppose compressions and tractions, thus the lower their mechanosensitivity. Conversely, a cell with a frame poor in protein filaments has a reduced capacity for mechanotransduction and has little advantage from external mechanical stimulation when it activates its vital functions.

Mechanobiology also studies cellular adaptation to an external load (stimulus)[4]. The mechanical forces acting on the organism are biological regulators, of equal importance to chemical and electrical ones. Among the various functions that a cell can perform, mechanoregulation allows it to react to a mechanical stimulation by modifying its morphology and molecular architecture in order to be able to counteract more the external stresses more effectively[5]. However, an altered mechanosensitivity, in excess or in defect, may produce an anomalous behaviour of the cell which, having become too sensitive, or resistant, to the interactions with the external environment, can progressively alter the functionality of its entire fabric, leading it to a pathological state. The hypothesis that cells have a mechanochemical regulatory system[6] is now well accepted by the scientific community of mechanobiologists. Based on the intensity and direction of the mechanical impulse, the cell can accelerate or restrain the same enzymatic reaction, or suspend it in order to activate a new one. Each organelle of the cell, including the nucleus and chromosomes, is bound to the lining membrane by a complicated intertwining of microtubules[7]. The focal adhesions are the points of the cellular membrane where the microtubule bundles originate and, through them, they act as sorting nodes of the external forces. Focal adhesions are defined as “mechanical-sensory organelles” precisely because, through the dense network of microtubules, they are able to distribute the concentric and eccentric forces acting on the static equilibrium of the cell on all the cellular elements[6].

Whenever a microtension activates a cellular receptor, a biological function is initiated[8]. In fact, in addition to stretching the microtubules of focal adhesions, the micro-tensions that reach the cell membrane can dilate the micropores, open the ion channels, move the free terminals, pull the transmembrane proteins and arrange the hormone receptors to bind with the corresponding chemical messengers. Therefore, there is an intricate system of mechano-couplings with which each site of the cell membrane, sensitive to precise mechanical stimulation, is linked to a specific cascade of chemical reactions[9] which can even initiate certain genetic transcriptions. As the mechanical stimulus varies, the cell therefore changes its vital activity. The ability to continuously remodel bone is a typical example of mechanobiology. The non-biological component of bone tissue is formed by a dense network of collagen filaments and calcium crystals. Collagen gives the bone elasticity, while calcium crystals give it mechanical strength. The strong atomic bonds that generate water between the organic component of collagen and the inorganic component of calcium crystals make hydroxyapatite, the non-biological component of bone tissue, very similar to a cemented paste such as ceramic[10]. Water is therefore the third most important element of bone tissue, without water the bone calcification would disintegrate[11]. The biological component of bone tissue is instead made up of cells that manage the hydroxyapatite deposits. Osteoblasts and osteoclasts respectively assemble or remove inorganic material from the surface of the bones. Osteocytes control the mineral integrity of the innermost layers of bone tissue. The progenitor cells, located just below the surface, allow the renewal of the deep and superficial cellular components of the bone. The dense network of communication between these four types of cells makes bone a mechanical material capable of modifying its shape and structure based on the mechanical forces that stress it[12]. The biomechanical characteristics of a bone are described by its two main axes: the anatomical axis and the mechanical axis (box A of figure 1). The anatomical axis slides from one end to the other of its greater length, curving in the points in which the muscles are inserted and straightening in proximity of the articular extremities. The mechanical axis, on the other hand, linearly (ideally) combines the garments and represents the direction of the resultant of the forces acting on it. Generally, a joint lever concentrates the muscular forces along the anatomical axis, to then direct them along the mechanical axis. The geometric differences between anatomical axis and mechanical axis lead the bones to be continually subjected to shearing, traction, compression and torsion forces (box B of figure 1). If the bone is stressed by infrequent overloads, the intercellular, trabecular and lamellar spaces of the bone tissue passively dissipate the excess biomechanical tension (box C in figure 1). If, on the other hand, the overload becomes recursive, the cellular matrix of the bones responds actively, alternating phases of ablation and cell replication with phases of decalcification and recalcification of the non-biological bone matrix. The bone segment is thus reshaped and its stratification rearranged, in order to align the anatomical axis as much as possible with the mechanical one and to reduce the stress due to excess load (box D of figure 1).

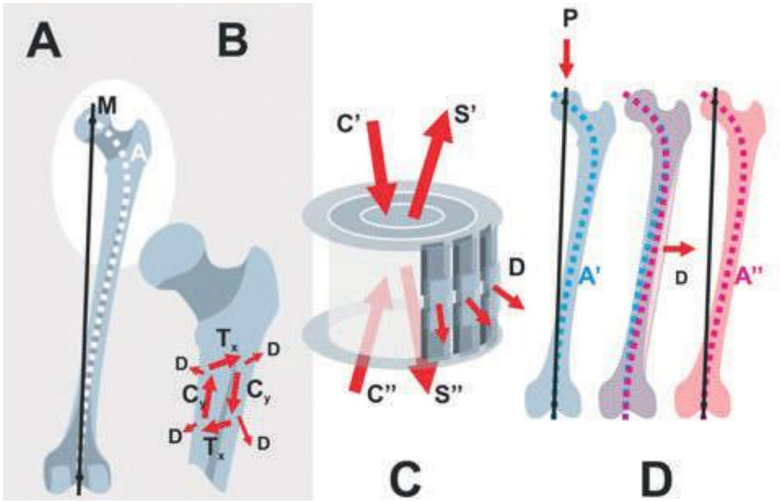


FIGURE NO. 1 BONE TISSUE REMODELLING. A) THE LONGITUDINAL SECTION OF A BONE DEVELOPS ALONG TWO MAIN AXES: THE ANATOMICAL AXIS, WHICH EXTENDS FROM ONE END TO THE OTHER OF ITS GREATER LENGTH (LINE A IS THE WHITE DOTTED LINE), AND THE MECHANICAL AXIS (LINE M BLACK LINE), WHICH REPRESENTS THE DIRECTION OF THE RESULTANT OF THE FORCES ACTING ON IT. B) FROM A BIOMECHANICAL POINT OF VIEW, WHEN THE BONE IS OVERLOADED FROM EXTERNAL FORCES, THE COMPRESSION (CY) AND SHEAR (TX) COMPONENTS CLOSE A CIRCUIT OF FORCES WHOSE RESULTING (D) ARE DIRECTED TOWARDS THE PERIPHERY. C) THIS REPRESENTS THE OSCILLATIONS AND VIBRATORY ACTIONS (D) OF THE INTERCELLULAR, TRABECULAR AND LAMELLAR SPACES OF THE BONE TISSUE THAT DISSIPATE THE EXCESS OF MECHANICAL TENSION CAUSED BY THE COMPRESSION ACTIONS (C', C'') AND SLIDING (S', S''). D) UNDER A RECURSIVE LOAD SUCH AS THE WEIGHT FORCE (P), THE BONE MASSES, DISTRIBUTED ON AN INITIAL ANATOMICAL AXIS (A'), UNDERGO A SLOW REMODELLING (D), UNTIL THEY ALIGN THEMSELVES WITH A NEW ANATOMICAL AXIS (A'') WHICH, BEING AS CLOSE AS POSSIBLE TO THE MECHANICAL AXIS, REDUCES THE STRESS DUE TO EXCESS LOAD.

MECHANOTHERAPY

Mechanotherapy studies the therapeutic potential of the mechanical forces that are either passively applied on the human body, or actively produced by a voluntary and autonomous movement, to induce an adaptation reaction that modifies, and improves, the functions[13]. The term was coined in the 19th century to define "the use of manual mechanical stresses to treat injuries and illnesses", replaced in the 20th century first with the term "massotherapy" and later extended to "all physical therapy interventions which, with the use of physical exercise, allow recovery from osteoarticular and muscular injuries". The 21st century's definition of mechanotherapy is based on the principles of mechanobiology and provides for "the therapeutic intervention that reduces and reverses the damage condition of an organ, or promotes the integration and stability of its functions, applying mechanical stimulations at the level of the tissue, cells and molecules that constitute it"[14]. The development, recomposition, degradation and reconstruction of organic tissues such as bones, cartilage, tendons, muscles including the heart, lungs and other internal organs, arteries and veins, glands such as the liver, adrenal and the breast, the skin and the nerves, also depend on the intrinsic and extrinsic mechanical signals to the organism3. The system that the human body possesses and which deals mainly with generating, absorbing and transmitting the forces that move it, is the musculoskeletal system. Although scientific literature outlines the term mechanotherapy with clinical interventions, rehabilitation (reduces and reverses the condition of organic damage) and prevention (promotes the integration and stability of organic functions), it is evident that any training process of the musculoskeletal system can be redefined based on the concepts of mechanobiology. Just as the practice of physical exercise for the most varied recreational, health or competitive purposes can be compared to a mechanotherapy intervention.

In conditions of strong mechanical stress, such as those produced by intense and prolonged sporting practice (box A of Figure 2), the shape and structure of the musculoskeletal system change continuously, in compliance with the "fit-for-purpose" condition12. This myofibrillar and osteo-articular remodelling process (box B of Figure 2) optimises the strength of muscle contraction, postural stability, mobility of the joint levers and tendon elasticity to increase the mechanical performance of those gestures that are typical of the sporting discipline carried out (box C in Figure 2).

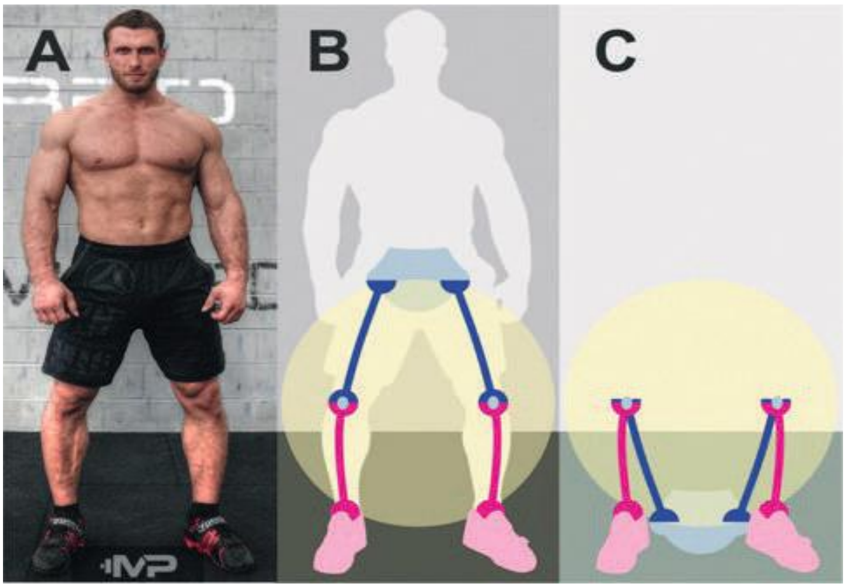


Figure No. 2 An example of Anatomical Remodelling.
A)The morphological structure of Dimitrij Vjaceslavovic Klokov (born in 1983, 105 kg body weight, 183 cm height), former weight lifter (169 kg maximum lift in the Snatch, 232 kg maximum lift in the Clean), participated in the 2008 Beijing Olympics, retired from competitions in 2015. B) Due to the high overloads that Klokov has lifted throughout his career, his lower limbs have undergone anatomical remodelling. If viewed from the bottom upwards, the anatomical axes of the tibiae are curved outward, while those of the femurs are inward. C) This somatic adaptation has allowed the athlete to optimise the mechanical performance of movement and stability of his pelvis, along the entire vertical excursion (the diameter of the yellow circle) that is required in the technical movements of weight lifting.

ANATOMICAL ADAPTATION

The transcription of DNA is therefore at the heart of anatomical adaptation. In specific traits of this double genomic helix are coded the assembly instructions of the organic molecules that make the muscle cell sensitive to the mechanical signals of the external environment. Among the hundreds of types of these mechanoreceptors, there are five that perform sensory functions[16]. 1) Adenosine monophosphate kinase (AMPk) is the protein enzyme sensitive to concentrations of stoppers and glycogen[17]. When the stocks of these two energy substrates are drastically reduced, the AMPk stimulates the cell to re-synthesize them. 2) Hypossia-Inducible Factor prolyl-hydroxilases (HIFph) is the anaerobic enzyme factor that senses the critical reduction of oxygen and causes the cell to metabolise lactate and other carbonate ions, to continue producing energy[18]. 3) The adrenergic receptors, together with 4) calmodulin (CaMk), regulate the flow of calcium ions, behaving respectively like the accelerator and the clutch of a car. If the stimulation of adrenergic receptors pours more ionic fuel into the muscle engine, calmodulin, like a friction block, deactivates the effect. 5) Titin kinase (Tk) is a protein with mechano-enzymatic properties, that is sensitive to mechanical stresses produced by muscle cells in contraction[19]. Where the integrity of the muscle fibre is compromised by a strong mechanical overload, Tk stimulates the aggregation of cytoskeletal reinforcement proteins.

Having a high concentration of these mechanoreceptors in muscle fibres inevitably leads to a series of advantages for training and performance: 1) The higher the concentration of AMPk, the greater the bioenergy stocks of phosphates and muscle glycogen, and the longer it is possible to contract the muscles and then train. 2) The higher the level of HIFph, the more the muscle cell can obtain energy in the absence of oxygen, so the more an exercise can be repeated continuously. 3) The more adrenergic receptors there are on the cell surface, the greater the flow of calcium ions that activates the sarcomeric contraction, the more power can be expressed at each maximal test. 4) The more CaMk is present in the myocellular sarcoplasm, the sooner the muscle cell relaxes and begins to regenerate, the less time can be devoted to recovery. 5) The more Tk is present in the myofibrillar cytoskeleton, the greater the resistance to the inertial overload of myofibres, the less structural damage and muscle pains are experienced in the post-workout period. Moreover, these five types of sensory proteins activate a further cascade of growth factors (IGFs) and enzymatic modulators, such as actinine (Akt) and the rapamycin mechanoreceptor (mTOR)[20], which lead to cellular hypertrophy through both the reinforcement and replication of contractile units, both for the storage of bioenergy, water and nitrogen sources[21]. Consequently, when the intensity of the exercises reaches the maximal levels, the replication of the sensory and enzymatic proteins is accelerated thanks to the increase in IGF, Akt and mTOR concentrations in muscle tissue.

There is also a further group of mechanosensitive molecules, such as the Mitogen Activated Protein Kinase (MAPk), which respond to the mechanical stresses to which the active muscle cell is subjected. These mitogenic modulators transduce the longitudinal and transversal components of the extra-cellular forces into signals of replication of the sarcomeres, respectively, towards sequential chaining or parallel alignment. Therefore, if a high number of concentric exercises is performed, the MAPk will tend to induce the genesis of sarcomeres in parallel and the anatomical muscle adaptation will manifest itself with the increase in maximal strength. In contrast, if numerous eccentric contractions are made, the MAPk will mainly start the sequential chaining process of the sarcomeres and the anatomy of the muscles will adapt to generate maximum expressions of explosive force.

Finally, muscle cells are equipped with self-regulating signals such as factors inhibiting genetic transcription, of which myostatin (mSTAT) is an example, and self-disintegration factors, also called Tumor Necrosis Factor (TNF). When the myofibril has completed the regeneration phases, mSTAT stops the production of additional cellular material[22]. The higher the presence of mSTAT inside the cell, the more the activity of gene transcription is suspended, the lower the production of new cellular material, the lower the effects of training. If, on the other hand, the myofibril reaches the biological limit, TNFs have the task of interrupting all the biological functions. The limit of cellular survival occurs whenever a high number of mechanostimulations deriving from, for example, an excess of inflammatory polypeptide cytokines, from the total depletion of energy stocks, from a strong internal state of dehydration, from the partial or total demolition of total contractile and support structures due to intense muscular efforts.

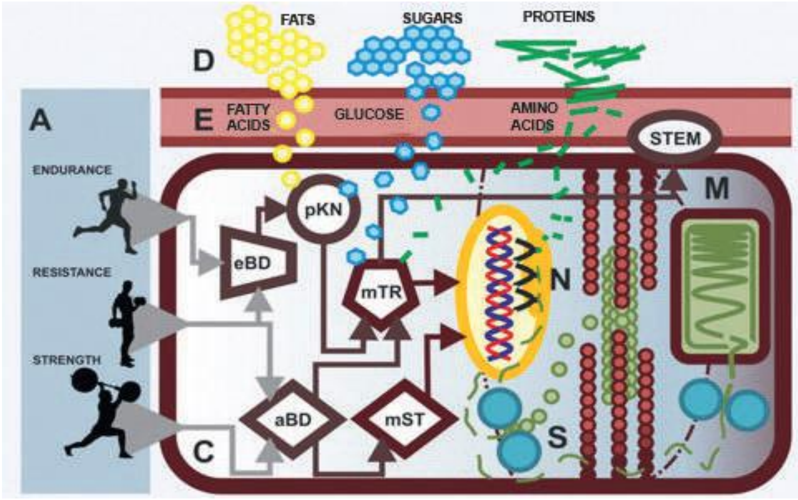


Figure No. 3 Simplified diagram of Cellular Mechanotransductions. Improve ENDURANCE, stimulate an initial complex of mechanoreceptors (eBD, endurance builders) that activate phosphate and glycogen storage processes (pKN, phosphate-kinase). Strength exercises, on the other hand, stimulate a second complex of mechanoreceptors (aBD, anabolic builders) which, simultaneously, activate genetic transcription (mTR, the mechanoreceptor for genetic transcription) to produce new contractile proteins and cancel the limit after which cellular biological activities are suspended (mSTAT, myostatin). Finally, exercises aimed at muscle development (RESISTANCE) stimulate both the eBD and aBD pathways. All the elements necessary for the formation of new cellular material come from the bloodstream (E) and from the deposits of fat, sugar and protein (D) distributed throughout the body. When the cellular volume (C), the sarcomeric volume (S) and the mitochondrial cell volume (M), the respective sites of cellular material storage, muscle contraction and energy production, reach an insufficient size for the life of the myofibril, the genetic transcription signals (mTR) promote the replication of the cell nucleus (N) through the activation of new satellite cells (STEM).

As a result, the more TNF are concentrated in the muscle tissue, the greater the inflammatory state, dehydration and malnutrition, and the more the practice of physical exercise can lead to a chronic condition of overtraining. Anatomical adaptation must therefore produce a change in the concentrations and types of proteins that regulate cell mechanosensitivity. Different training programmes lead to different levels of anatomical adaptation, as a result of different degrees of activation and repression of specific genomic replication processes of sensory proteins (Figure 3).

MUSCLE MEMORY

Recent experiments suggest that myofibrils contain a form of cellular memory capable of remembering the levels of cellular strength and development obtained in previous anatomical adaptation programmes[23]. This memory is contained in the myonuclei, the cellular nuclei of muscle fibres[24]. Muscle fibres are multinucleated cells, with hundreds of nuclei distributed over their entire length. Each nucleus can control biological activity and genetic transcription in a restricted cellular area, called the cellular domain. The number of myonuclei can change depending on cellular development. As the size of the muscle fibre increases, the satellite cells (which are specific stem cells produced during embryonic development), in a quiescent state (i.e. unable to proliferate) and placed along the myofibrillar coating lamina, are activated, replicated, and differentiate into myoblasts (progenitor cells of muscle fibres), adding the number of nuclei necessary to assist the development phase of cell syncytium (the fusion of multiple cells together and the coexistence of several nuclei in a single cell body), before deactivating and return to a state of quiescence[25].

The proliferation time of stem cells is about 1-2 days after an overload training session and precedes the remodelling (anatomical adaptation) myofibrillar phase16. In dissectionistic studies on animal guinea pigs, it was observed that after 28 days of interrupted physical activity, the volume of a muscle fibre was reduced by 50% while the number of its myonuclei remained unchanged[26].

14 days after resuming physical exercise, about 60% of the total muscle fibre volume previously lost was reacquired without altering the number of myonuclei[27]. With current bioptic techniques it is possible to count the number of satellite cells in a state of quiescence, activation and proliferation in human muscle tissue, thus observing the genetic effects of the anatomical adaptation induced by sports training[28]. The 1990 European powerlifting champion, Anders Eriksson, who later became a professor at Umeå University (Sweden), compared, in 1999, the muscle biopsies of ten Swedish national powerlifters with those of four elite athletes of other sports. In his research, Prof. Eriksson found that in the muscles of the athletes who have trained multi-year programmes with overloads, they count a number of myonuclei of 70% higher than those of the athletes trained with other programmes[29].

The histological differences observed in the two groups of athletes are attributable to three factors. Firstly: it would seem that maximal mechanical stimulations, such as those produced by training with overloads, always activate a supernumerary proliferation of myonuclei with respect to the actual physiological demands[28]. Secondly: the more cellular nuclei are present on the surface of the muscle fibre, the more enzymatic and sensory proteins are produced, the greater mechanosensitivity and speed of mechanotransduction are acquired by the muscle cell[29], the more effective will be its capacity for anatomical adaptation. Thirdly: myonuclei have a rather prolonged half-life and remain on the surface of myofibrillar synchin for a long time, even after the latter, due to a lack of mechanical stimulus, has atrophied and lost most of its enzymatic proteinaceous, sensorial, structural and contractile worth.

Roughly 10,000 molecules are produced by the genetic transcription induced by physical exercise[30]. The production of each of these is characterised by a specific type of mechanostimulation and can be assembled only if a specific enzyme complex is present in the cell. As each training programme prepares the cellular environment to transcribe only some genetic expressions, it follows that the myonuclei activated, for example, by the practice of exercises for organic resistance, pour ribonucleic acids (messengers of genetic transcripts) into the cytoplasm different from the myonuclei activated by the practice of exercises for muscle strength. Under these conditions, the population of myonuclei activated at each new stage of training adds to the already existing one, increasing the sensitivity of the cell to respond to mechanical stimuli of different nature (figure 4).

The ability of muscle tissue to possess cellular memory lies in the supernumerous number of myonuclei and in

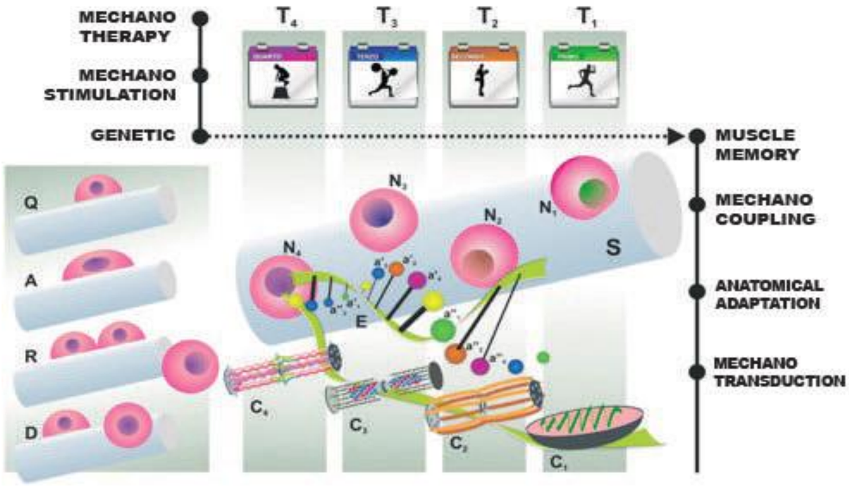


FIGURE NO. 4 MECHANOBIOLOGICAL MODEL OF MUSCLE MEMORY. MECHANOTHERAPY LEVEL: ACCORDING TO THE PRINCIPLES OF MECHANOBIOLOGY, A TRAINING PLAN CAN BE SEEN AS MECHANOTHERAPY, AND EACH EXERCISE THAT COMPOSES IT CAN BE ASSOCIATED WITH A MECHANOSTIMULATION. MECHANOSTIMULATION LEVEL: A MECHANOSTIMULATION (T1, T2, T3, T4) IS EFFECTIVE WHEN IT CAUSES THE MUSCLE CELL TO PRODUCE A GENETIC RESPONSE. GENETIC LEVEL: IF THE INTENSITY REACHED IN TRAINING PROGRAMMES IS MAXIMAL, THE MUSCLE CELL MAKES USE OF ITS QUIESCENT (Q) STEM CELL KIT, ACTIVATES IT (A), REPLICATES (R), DIFFERENTIATES IT (D) AND PRODUCES NEW MYONUCLEI. MUSCLE MEMORY LEVEL: WITH THE INCREASE IN MYONUCLEI DEPOSITION (N1, N2, N3, N4) ON THE MYOCELLULAR SYNCYTIUM (S) MYOCELLULAR MEMORY ALSO INCREASES. MECHANO-COUPLING LEVEL: EACH MECHANICAL STIMULATION IS COMBINED WITH THE FORMATION OF A SPECIFIC GROUP OF MYONUCLEI (T1 → N1; T2 → N2; T3 → N3; T4 → N4). ANATOMICAL ADAPTATION LEVEL: DURING THE REALISATION OF THE DIFFERENT TRAINING PROGRAMMES, ONLY CERTAIN PARTS OF THE DOUBLE HELIX (E) ARE TRANSCRIBED (T1 → A'1, A"1; T2 → A'2, A"2; T3 → A'3, A"3; T4 → A'4, A"4). MECHANOTRANSDUCTION LEVEL: THIS SELECTIVE TRANSCRIPTION PROMOTES THE FORMATION OF DIFFERENT CELLULAR COMPONENTS (A'1, A"1 → C1; A'2, A"2 → C2; A'3, A"3 → T3; A'4, A"4 → T4). IT FOLLOWS THAT, AT EACH TRAINING CYCLE, THE MUSCLE FIBRE IS ENRICHED WITH A CONSIDERABLE NUMBER OF RECEPTORS, ENZYMES AND CHARACTERISTIC COMPONENTS (T1 → C1; T2 → C2; T3 → C3; T4 → C4). THEREFORE, THE PROCESS OF MUSCLE MEMORY CONSISTS IN QUICKLY RECALLING, WHENEVER THE NEED ARISES, THE GENETIC TRANSCRIPTION BEGUN AT THE MOMENT OF MYONUCLEI FORMATION.

the prolonged permanence of their active state[24]. Muscle memory is the phenomenon of rapid development of muscle mass that is observed with the resumption of training in advanced athletes, practicing mainly sports of strength and power, continually subjected to long cycles of training aimed at developing strength and muscular hypertrophy. This cellular phenomenon, specific to the muscular system, is associated with the memory and memory processes of motor skills, typical of the central nervous system, to accelerate the restoration of a previous physical condition when certain mechanical stimulations (exercises) are re-proposed.

THE CYCLIC HYSTERESIS OF ANATOMICAL ADAPTATION

The term detraining defines the extraordinary capacity of the organism to demolish unused cellular structures, making the energy and plastic resources released available to the organism, in order to react quickly to new mechanostimulation. Detraining begins as soon as a training programme is interrupted, or when the parameters of frequency, volume and intensity of the mechanostimulation that constitute it are significantly changed[31]. Detraining can be accidental, following an injury, or planned, when you move on to a training cycle characterised by mechanical stimulations that do not recall those of the cycle that has just been abandoned[32]. Both of these forms of detraining involve a substantial loss of cellular genetic activity which, due to the effect of muscle memory, does not follow a linear regressive course. During the first two months of detraining, therefore, there is an apparent residual trace of the anatomical adaptation obtained before the termination of the training programme. The more the athlete is trained, the more the training cycle has been structured with complex exercises, performed at high intensity for a long period, the more the residual effects produced by detraining tend to remain stable and permanent[33]. The term retraining, on the other hand, defines the phenomenon of resuming the level of anatomical adaptation that was reached before the detraining phase. Generally, but not exclusively, retraining occurs when the same mechanostimulations are used that constituted the training programme performed before the detraining period. Since in the retraining process the staminal phase is skipped and, therefore, the formation of new myonuclei, the more the resources of myonuclei and genetic messengers of myocellular syncytium are preserved, the more the genetic memory contained in their nucleic acids is exploited, therefore the faster the process[24]. Thus, the time taken to return to the previous state of anatomical adaptation is always less than the time taken to reach it. The continuous alternation of detraining and retraining phases gives the phenomenon of anatomical adaptation the mechanical property of cyclic hysteresis (Figure 5). Hysteresis is a characteristic possessed by all the mechanical and biological systems that change over time. The hysteresis cycle (from the Greek word hystéresis which describes the tendency to delay the loss of a condition) is also called the hereditary cycle because, in the changing system, it tends to leave an "permanent" trace of the previous conditions which may recur in the future.

The traces of cellular memory left by an exercise programme condition the residual effects of the anatomical adaptation that the training itself produces. Depending on the way in which they are cyclically recalled throughout the training plan, these "permanent" traces can have positive or negative feedback on competitive performance[34]. In a recent reassessment of the terms used in the training methodology, each training programme was divided into three phases, each of which can be associated with one of the three traits that constitute the hysteresis cycle of the effects of anatomical adaptation: 1) an accumulation phase, in which the programmed anatomical adaptations are produced; 2) a transformation phase of the residual effects of anatomical adaptation to improve performance; 3) a phase of realisation of the maximum expression of performance obtained as a sum of the cumulative effects of the previous anatomical adaptation[35].

CONCLUSIONS

In the classical theory of training programming, an annual training plan generally begins with a preparatory period dedicated to general anatomical adaptation[36]. The connective, myofibrillar and skeletal remodelling that takes place in this period, makes it possible to predispose the bones, ligaments, tendons, muscles and heart to respond more quickly to the mechanical stresses produced by the loads and technical exercises planned for the following competitive period[37]. For the consequences due to the detraining process, it is imperative to remember that the greater number of months that the preparatory period lasts, the more the anatomical adaptation achieved will remain stable during the subsequent competitive period[33].

An example of an annual plan of this type, aimed at athletes of strength and power sports, is divided into five phases, three in the preparatory period - (1) muscle development, (2) strength, (3) power -and two in the competitive one - (4) development of maximum performance and (5) maintenance of the maximum level of performance38. An annual plan structured in this way envisages increasing the muscle mass (in phase 1), increasing its strength (in phase 2), to be used (in phase 3) as the basic physical condition for the development of power, which will serve (in phase 4) to quickly reach the maximum performance peaks that will finally be consolidated, stabilised and made routine (in phase 5)[38]. To achieve the anticipated muscular adaptation, in the preparatory period, and the transfer of its effects to performance, in the competitive period, the mechanical stimulations (exercises) inserted in the five phases will progressively produce a decrease in volume and an increase in intensity. From 3-6 sets of 10-15 repetitions with loads of 50-75% compared to the maximum, which stimulate the muscular hypertrophy sought in phase 1, we move on to 3-5 sets of 4-8 repetitions with loads around 80- 90% of the maximum to increase the maximum force, which is the goal of phase 2. In phase 3 of the preparatory period, the speed of execution of the exercises to train the power is increased, with 3-5 sets of 2-5 repetitions and loads of 75- 95% of the maximum. Finally, entering phase 4, the competitive period begins and so only 1-3 sets of 1-3 repetitions are performed with loads exceeding 90% of the maximum. In this phase, athletes aim at achieving a new personal record and, having reached this, they move on to phase 5 where they perform 2-3 sets of 6-8 repetitions with loads of 80-85% of the new maximum[38].

The logical sense underlying this annual plan model completely satisfies the principle of the cumulative effects of anatomical adaptation. However, by applying the mechanical principles of detraining and cyclic hysteresis, we can highlight some critical points.

In the phase dedicated to muscle development (phase 1) the muscles are subject to hypertrophy. The myofibrils contractile filaments thicken, the sarcoplasm becomes denser and is enriched with water, salts and energy substrates. The sarcomeric

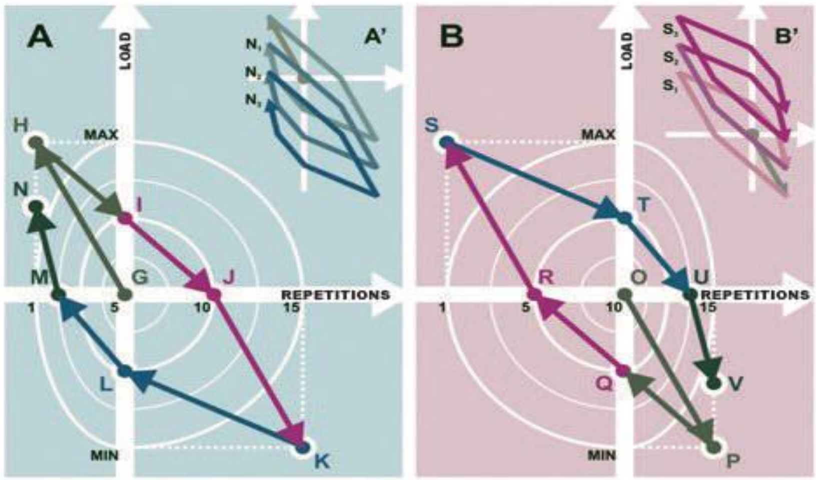


Figure No. 5 Two Mechanobiological Models of Cyclic Hysteresis for General Anatomical Adaptation. In both models there are four phases: accumulation (light grey), transformation (magenta), endurance (blue) and peak (dark grey). Model A involves an accumulation of force and a transformation into resistance. Model B foresees an accumulation of endurance and a transformation into strength. If in a maximal exercise 5 repetitions are performed (G), after a strength programme consisting only of single sets (H), it can be seen that: to finish 5 repetitions a higher load than the initial one required (I); with this initial load, more than 5 repetitions are now performed (J); the load used in the 15 repetition set is very low (K). Continuing with an endurance programme, it is observed that: the load in the set of 5 repetitions becomes less than the initial one (L); with the initial load it is now possible to carry out only a couple of repetitions (M); the load that can only be lifted once is reduced (N). If, instead, in an exercise you can only perform 10 repetitions (O), after a programme dedicated to endurance carried out with set of 15 maximum repetitions (P), it can be seen that a load less than the initial condition is necessary to finish 10 repetitions (Q) and with the initial load less than 10 repetitions (R) can be performed. As a result of exercises performed with single sets only, strength is acquired (S). It is thus possible to carry out 10 repetitions with a very high load (T) and with the initial load the set can be extended beyond the 10 repetitions (U). Therefore, if one follows the training cycles that go from strength to endurance (A'), there is the risk of losing strength (N1> N2> N3), on the other hand, if there are successive training cycles that pass from endurance to strength (B') , it is possible that strength levels increase (S1 <S2 <S3).

cytoskeleton thickens and branches. Intracellular frictions and mechanical strengths increase, as does the energy cost of the flow of intrasarcomeric protein filaments and of the stacking of intracellular sarcomeres. The overall effect of this remodelling will reduce the speed of muscle contraction. In the subsequent phase, dedicated to maximum force (phase 2), the mechanical stimuli that reach the muscle cells become more intense and less frequent. By prolonging the recovery time between the series, the muscle fibres have more time to oxygenate and the cellular processes of hypoxia-related hypertrophy are minimised. Furthermore, the reduction in the number of repetitions to be performed in the set leads the muscle cells to choose the fastest bioenergetic processes based on phosphates, and discard the slower ones of glycolytic substrates. Under these conditions, the enzymatic processes linked to the use of the energy pathways of sugars and fats are degraded and the cellular recovery capacity is reduced overall. However, by continuing to receive intense mechanical stimuli from the extreme overloads of this period, the myofibrils keep their protein assets intact, they continue to strengthen their contractile and support structures, while they begin to lose the volume of surplus energy substrates, thus becoming resistant at infrequent maximum loads. The preparatory period is completed with the development of power, choosing to perform explosively maximum force exercises and technical competition movements. To prevent the onset of fatigue from slowing down the execution, each set must be carried out with a few repetitions. Recovery can be reduced, if mental concentration tends to be easily lost, or prolonged, if energy stocks are slowly restored. The choice to increase the loads, set after set, depends on the speed of execution, which must remain constant and maximal with each repetition.

In the development phase of maximum performance, the first phase of the competitive period, mechanical stimulations are generated mainly by the specific exercises used to improve competition performance. These exercises, and their variants, are biomechanically and neurologically very complex, performed in a very short time, contracting a high number of muscles. The more they are repeated in training, the more their technical and metabolic efficiency improves.

Performing them continuously and at high speed requires a very high energetic, muscular and mental effort. Therefore, it is possible to choose to perform just a few sets, with a few repetitions for several sessions a day. However, the previous training period has developed a reduced capacity for recovery based on slow aerobic processes. Furthermore, the increase in overloads, which began during the period of muscular development and continued in the subsequent period of maximum strength, has always occurred at sub-maximum speeds. Finally, the only period dedicated to power was not enough to learn how to perform the race movements at maximum speeds. Therefore, in the competitive period it becomes difficult to increase the frequency of training without producing an excess of cellular over-stimulation, an acute inflammatory state, a debilitating condition, a psychophysical refusal to train, an overtraining condition and a greater predisposition to injuries. This brings us to the final phase of the annual plan, which aims to replicate the performance at maximum power several times, with the nervous and muscular systems in unsuitable conditions to create explosive movements and recover immediately. Without resilience and rapid muscle contractions, you cannot complete a volume of work sufficient to produce stable improvements in the performance power of technical movements.

Avoiding the processes of detraining and cyclic hysteresis, when planning training programmes, can lead to not achieving the expected results. If you look for a parameter that must have constant growth throughout the training plan, instead of choosing the multiform parameter of muscle strength, there is the alternative of the most undifferentiated speed of execution of technical movements. In the preparatory period, for example, after a brief phase of learning correct movements, one can focus on increasing speed and load in parallel on a large number of different exercises, all derived from specific technical movements[39]. If, for each of these exercises, the speed of the competition movement is reached and exceeded, the mechanostimulations that stimulate the genetic transcription of the muscle fibres will produce a more suitable myofibillary remodelling to contract quickly. Continuing with the example, in the competitive period, instead, it is possible to decide to increase speed and load exclusively for the technical competition movement. In this programming mode, it can be performed a few times a week, to avoid overtraining the memory patterns that form it and to bring the myofibrils of the muscles involved in its realisation into an acute inflammatory state. In this last period, the training volume is guaranteed by the choice to perform many times a week, keeping the execution speed high, a few exercises which are useful in correcting the most recursive technical defects. This change of perspective fully satisfies the needs of modern sport of weightlifting, record after record, the expressions of muscular power[40].

REFERENCES:

1. Shivashankar GV, Sheetz M, Matsudaira P. Mechanobiology. Integrative Biology. 2015;7(10):1091-1092.
2. Jansen KA, Donato DM, Balcioglu HE, Schmidt T, Danen EH, Koenderink GH. A guide to mechanobiology: Where biology and physics meet. Biochim Biophys Acta. 2015;1853(11 Pt B):3043-3052.
3. Pedersen JA, Swartz MA. Mechanobiology in the third dimension. Ann Biomed Eng. 2005;33(11):1469-1490.
4. Van der Meulen MC, Huiskes R. Why mechanobiology? A survey article. J Biomech. 2002;35(4):401-414.
5. Ingber DE. Mechanobiology and diseases of mechanotransduction. Ann Med. 2003;35(8):564-577.
6. Ingber DE. Tensegrity-based mechanosensing from macro to micro. Prog Biophys Mol Biol. 2008;97(2-3):163-179.
7. Ingber DE. Tensegrity I. Cell structure and hierarchical systems biology. Journal of Cell Science. 2003;116(7):1157-1173.
8. Ingber DE. Tensegrity II. How structural networks influence cellular information processing networks. Journal of Cell Science. 2003;116(8):1397-1408.
9. Warden SJ, Thompson WR. Become one with the force: optimising mechanotherapy through an understanding of mechanobiology. British journal of sports medicine. 2017;51(13):989-990
10. Zaffe D. Some considerations on biomaterials and bone. Micron. 2005;36(7-8):583-592.
11. Nyman JS, Roy A, Shen X, Acuna RL, Tyler JH, Wang X. The influence of water removal on the strength and toughness of cortical bone. J Biomech. 2006;39(5):931-938.
12. Mellon SJ, Tanner KE. Bone and its adaptation to mechanical loading: a review. International Materials Reviews. 2012;57(5):235-255.
13. Khan KM, Scott A. Mechanotherapy: how physical therapists' prescription of exercise promotes tissue repair. British journal of sports medicine. 2009;43(4):247-252.
14. Huang C, Holfeld J, Schaden W, Orgill D, Ogawa R. Mechanotherapy: revisiting physical therapy and recruiting mechanobiology for a new era in medicine. Trends Mol Med. 2013;19(9):555-564.
15. Coffey VG, Hawley JA. The molecular bases of training adaptation. Sports Med. 2007;37(9):737-763.
16. Wackerhage H, Lionikas A, Gray S, Ratkevicius A. 1.7 Genetic and Signal Transduction Aspects of Strength Training. In: Cardinale M, Newton R, Nosaka K, eds. Strength and Conditioning: Biological Principles and Practical Applications. Oxford, UK: John Wiley & Sons; 2011:77-85.
17. Hardie DG, Sakamoto K. AMPK: a key sensor of fuel and energy status in skeletal muscle. Physiology (Bethesda). 2006;21:48-60.
18. Metzen E, Zhou J, Jelkmann W, Fandrey J, Brüne B. Nitric Oxide Impairs Normoxic Degradation of HIF-1α by Inhibition of Prolyl Hydroxylases. Molecular Biology of the Cell. 2003;14(8):3470-3481.
19. Puchner EM, Alexandrovich A, Kho AL, et al. Mechanoenzymatics of titin kinase. Proceedings of the National Academy of Sciences. 2008;105(36):13385-13390.
20. Laplante M, Sabatini DM. mTOR signaling in growth control and disease. Cell. 2012;149(2):274-293.
21. Egerman MA, Glass DJ. Signaling pathways controlling skeletal muscle mass. Critical Reviews in Biochemistry and Molecular Biology. 2014;49(1):59-68.
22. Rodriguez J, Vernus B, Chelh I, et al. Myostatin and the skeletal muscle atrophy and hypertrophy signaling pathways. Cell Mol Life Sci. 2014;71(22):4361-4371.
23. Egner IM, Bruusgaard JC, Eftestøl E, Gundersen K. A cellular memory mechanism aids overload hypertrophy in muscle long after an episodic exposure to anabolic steroids. The Journal of Physiology. 2013;591(24):6221-6230.
24. Gundersen K. Muscle memory and a new cellular model for muscle atrophy and hypertrophy. The Journal of Experimental Biology. 2016;219(2):235-242.
25. Kadi F, Charifi N, Denis C, et al. The behaviour of satellite cells in response to exercise: what have we learned from human studies? Pflügers Archiv. 2005;451(2):319-327.
26. Bruusgaard JC, Gundersen K. In vivo time-lapse microscopy reveals no loss of murine myonuclei during weeks of muscle atrophy. The Journal of Clinical Investigation. 2008;118(4):1450-1457.
27. Bruusgaard JC, Egner IM, Larsen TK, Dupre-Aucouturier S, Desplanches D, Gundersen K. No change in myonuclear number during muscle unloading and reloading. Journal of Applied Physiology. 2012;113(2):290-296.
28. Andersen J. 2.2 Structural and Molecular Adaptations to Training. In: Cardinale M, Newton R, Nosaka K, eds. Strength and Conditioning: Biological Principles and Practical Applications. Oxford, UK: John Wiley & Sons; 2011:125-135.
29. Kadi F, Eriksson A, Holmner S, Butler-Browne GS, Thornell LE. Cellular adaptation of the trapezius muscle in strength-trained athletes. Histochem Cell Biol. 1999;111(3):189-195.
30. Allen DL, Harrison BC, Leinwand LA. Molecular and genetic approaches to studying exercise performance and adaptation. Exerc Sport Sci Rev. 2002;30(3):99-105.
31. Ratamess N. Adaptations to Anaerobic Training Programs. In: Baechle T, Earle R, eds. Essentials of Strength Training and Conditioning. Champaign, IL: Human Kinetics Publishers; 2009:94-119.
32. Fleck SJ, Kraemer W. The Detraining Phenomenon. In: Fleck SJ, Kraemer W, eds. Designing Resistance Training Programs 3rd Edition. Champaign, IL: Human Kinetics; 2014:241-259.
33. Zatsiorsky VM, Kraemer WJ. Timing in Strength Training. Science and Practice of Strength Training. Champaign, IL: Human Kinetics; 2006:89-107.
34. Counsilman BE. The residual effects of training. 1991;7(1):S. 5-12.
35. Issurin V. Block periodization versus traditional training theory: A review. 2008;48:65-75.
36. Bompa T, Carrera M. Phase 1: Anatomic Adaptation. Periodization Training for Sports: Human Kinetics; 2005:151-162.
37. Bompa T, Di Pasquale M, Cornacchia L. Anatomical Adaptation (AA). Serious Strength Training 3rd Edition: Human Kinetics 1:193-202.
38. Watthen D, Baechle T, Earle R. Periodization. In: Baechle T, Earle R, eds. Essentials of Strength Training and Conditioning. Champaign, IL: Human Kinetics Publishers; 2009:508-522.
39. Simmons L. Special Strength Development for All Sports. Westside Barbell; 2015.
40. Verkhoshansky YV. Special Strength Training: A Practical Manual for Coaches. Ultimate Athlete Concepts; 2006.

DONATO FORMICOLA
ADJUNCT PROFESSOR OF TRAINING THEORY, METHODOLOGY OF TRAINING AND SPORT KINESIOLOGY AT THE SUISM SCHOOL OF EXERCISE AND SPORTS SCIENCE AT THE UNIVERSITY OF TURIN; HE IS A SCIENTIFIC CONSULTANT FOR EVOLUTION, ITALY'S LEADING CLOUD SYSTEMS PROVIDER FOR TRAINING PROGRAMMES.
HE IS ALSO IS A LECTURER IN NUTRITION AND SPORTS INTEGRATION AT THE SCHOOL OF SPORTS NUTRITION AND INTEGRATION (SANIS); FEDERAL LECTURER AND TRAINING COORDINATOR AT THE PIEDMONT REGION COMMITTEE OF THE ITALIAN WEIGHTLIFTING FEDERATION (FIPE).

MASTERS WEIGHTLIFTING

While most people peak in terms of weightlifting potential in their twenties, there is a thriving competitive scene for those aged thirty-five and above – known as masters lifters.

Catering to masters weightlifters, whether they are novices or international competitors, can help you to grow your membership with a type of member who are especially valuable to a gym or club.

In this paper, we will look at why you should be looking to attract older weightlifters and how you will need to adjust coaching and programming to retain them.

After reading this paper, you should be ready to start building a masters section in your club.

MASTERS WEIGHTLIFTING

THE GROWTH OF MASTERS WEIGHTLIFTING

So called Masters weightlifting competitions, originally for those aged forty plus but now for thirty-five and over, have been held since the 1970s. The International Weightlifting Federation has recognised international masters competitions since 1992. However, recent years have seen a rapid increase in the number of masters participants at all levels in many countries. Many weightlifting clubs now have enough members aged thirty-five and above to form dedicated masters sections and masters competitions are regularly filled to capacity.

WHY ARE MASTERS WEIGHTLIFTERS VALUABLE MEMBERS?

Many weightlifting clubs focus the majority of their attention on younger lifters – especially those with the potential to compete at senior national competitions at some point. Those who are past their physical prime may seem less attractive prospects. However, these members can be valuable in many ways.

Being open to all age groups widens the potential membership of a club or gym. Over a third of the world's population is aged thirty-five or above – if you ignore this group you are turning your back on a lot of potential members.

Middle-aged members will tend to have higher incomes than younger ones. This means they will often be more interested in paying for additional things such as one-on-one coaching or branded merchandise.Having some older members can also have a positive effect on younger members by creating a more mature training environment.

If you have long term plans to develop young athletes, masters weightlifters can provide them! A proportion of middle-aged weightlifters will have children around the right age to be introduced to weightlifting. What better way for a youth weightlifter to develop than with a parent in the sport?

HOW TO EXPAND YOUR MASTERS MEMBERSHIP

There are two main ways to increase the number of masters weightlifters in your club: attract existing weightlifters or convince novices to get started in the sport. Both of these are valuable approaches.

Existing masters weightlifters will look for many of the same things in a club that all weightlifters want. Good coaching and a productive training environment are critical, along with a regular presence at competitions (both masters and younger age categories). Older weightlifters may also set more store by the social aspect of a club.

Getting non-weightlifters involved can be tricky. Weightlifting is a minority sport and many may not be aware of the benefits it could bring them. Some people will seek out a weightlifting club because they have seen weightlifting on TV, perhaps at the Olympics, and want to try it for themselves. However, the majority of potential weightlifters will not even know they will enjoy it until they try, so getting them through the door initially is the biggest challenge.

The main reasons why middle-aged people take up a new sport are to:

- **Improve health**
- **Take on a new challenge**
- **Get new social opportunities**

You can use all of these to attract and retain this kind of member. Happily, health advice to the public is now catching up with the science, so everyone is recommended to do some form of strength training regularly. If you offer an entry-level strength training course, you will be able to encourage participants to try weightlifting movements as part of that. A proportion of people who start to learn the weightlifting movements will set themselves the challenge of becoming proficient in them. It is a small step from there to them becoming a competing masters weightlifter.

Over a third of the world's population is aged thirty-five or above.

Another opportunity for members is lapsed weightlifters. People leave the sport for many reasons, including work commitments and having children. Often these other commitments will reduce over time, enabling an athlete to return to the sport. A friendly invite to come and train might be all that is needed. Can you think of anyone like this?

RETAINING MASTERS MEMBERS

Once you have attracted some older weightlifters to your club, you obviously want to encourage them to become loyal members. As with athletes of any age, progress is the critical thing for most masters weightlifters. If they feel like they are getting stronger and developing their technical skills, they are likely to stay motivated to continue. On the other hand, if progress stalls or if they don't think they will achieve their goals, you will risk losing them. Setting realistic expectations for progress and goals is therefore very important.

Competition is a great way to inspire masters weightlifters to commit to training regularly and to create long-term members. Dedicated masters competitions are very welcoming and provide an environment where older novices can start competing without feeling intimidated by younger athletes lifting huge weights.

Ultimately, the most important factor in whether masters weightlifters stay with you will be how well you have understood their personal goals and created an environment that supports them. Some may have aspirations to compete at a high level in masters weightlifting while other may be focused on keeping fit or even just enjoying practising the movements.

CHALLENGES OF MASTERS COMPETITORS

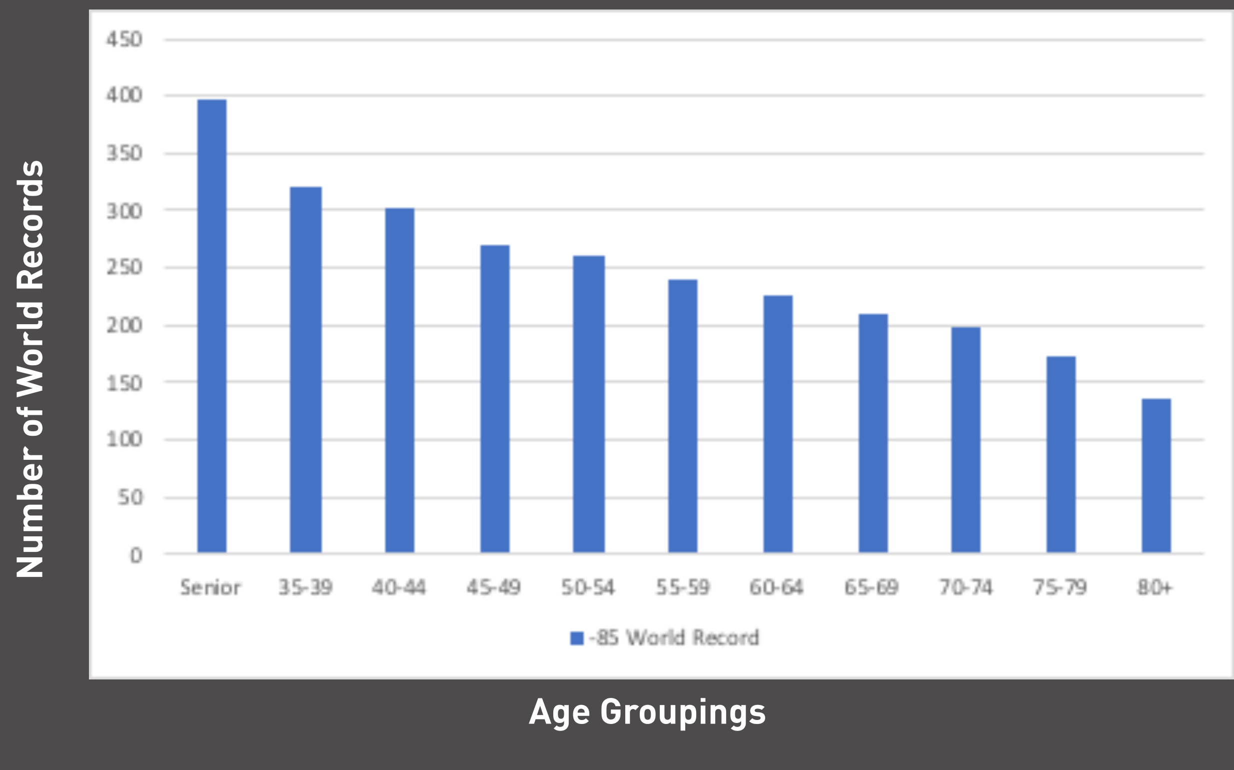
We know that as we age, several changes occur in our body that will impact our ability to lift heavy weights. Production of the main hormone involved in developing muscle mass, testosterone, peaks for men in the late teens and sees a steady decline from then until around the age of forty (Kelsey etal, 2014). A similar pattern is seen in women. Levels of human growth hormone production also drop steadily throughout our lives (Bartke, 2008).

These changes lead to a decline in the ability to maintain muscle mass along with a reducing neural ability to use the muscle that we have efficiently. Changes in our connective tissue also make us more prone to injury (Boss and Seegmiller, 1981).

There is evidence that older athletes suffer from fatigue more during training, seeing a greater reduction in power than younger people in the minutes after completing a heavy exercise (Dalton et al, 2012). Studies have also shown that recovery between training sessions takes longer as we age, possibly because we don't process protein as efficiently (Doering et al, 2017). Neural changes in the aging brain and nervous system can make it harder for older people to take in new information or learn new skills (Murman, 2015).

Mobility can also be an issue for masters weightlifters, especially those who come into the sport late and without a background in another sport. Flexibility at the hip and knee, both critical to weightlifting, generally decline with age (Roach and Miles, 1991) and other areas such as thoracic or shoulder mobility can be challenged more with age, especially in those with desk jobs. The steady decline in weightlifting potential is demonstrated by the weightlifting world records across age groups (see Figure 1). This chart shows the final world records for the recently retired men's -85 kg category across age groups.

Figure 1: The steady decline in weightlifting potential



It should be noted that some of the drop between senior and the first masters-age category will be caused by lower participation and the fact that masters competitors do not have the level of support that many senior athletes get from their national governing bodies. However, the pattern is clear and is repeated across all weight categories for men and women.

The world records in a similar weight category in powerlifting also show a decline with age but do not show such a dramatic initial drop – perhaps indicating that a significant proportion of that drop is due to loss of mobility and speed as opposed to maximal strength (see Figure 2 below).

FIGURE 2: Decline in powerlifting potential

Note that in powerlifting, the first masters age category is from age 40 to 49 and the categories span ten years as opposed to five in weightlifting. The most significant drop in performance comes between the 50–59 and 60–69 categories, hinting that maximal strength may be impacted more over that age range. This is supported by some evidence that changes in our muscles as we age affect rate of force development ahead of maximal strength (Canepari et al, 2010).

ADDRESSING THE CHALLENGES

It is important to consider the history of any weightlifter but this is especially true with masters athletes – they have lived longer so will likely have accumulated a wider variety of training experience (although this is not true for everyone – for some coming to weightlifting late in life, it is the first sport they have seriously pursued). They will also have had more time to accumulate injuries and other problems.

Make sure to ask about:

- **Training experience**
- **Injuries**
- **Medical history**
- **Diet**
- **Family commitments**
- **Work**

You should also carry out a full assessment of mobility and carry out functional movement screening to identify any potential problems. It is easy to make the mistake of treating older novices as more experienced than they actually are. Remember that biological age is important but training age is actually more significant when you are planning training sessions or longer term programmes.

While late starters in weightlifting can make relatively fast progress in the same way as younger beginners, usually they and you will have to accept that they will progress more slowly. Most of the time this is not a problem – older trainees are often more patient and are prepared to plan over a longer term.

There is a huge range in mobility levels among masters lifters – an ex-gymnast who regularly does yoga will obviously be much better in this regard than someone who has led sedentary life. However, it is much more likely that masters athletes will encounter mobility challenges. If a masters weightlifter has significant mobility problems, you may need to consider using variations of the weightlifting movements, either as a bridge to performing the full movements later or even as their competition style.

It is worth remembering that the power variations of the snatch, clean and jerk are all completely legal to use in competition. Just because someone can't sit into a deep overhead squat or clean catch, there is no reason why they can't compete. Some masters athletes even use the split snatch and split clean styles in competition. While these lifts are seen as old fashioned now, they are still perfectly fine to use in terms of the rules. Some athletes find that they can achieve a lower catch with a split than they can with a squat and the greater forwards-backwards margin for error helps with consistency. Athletes who use the split for snatch, clean and jerk also have the advantage of three times as much practice on the split.

As we saw earlier, the data on weightlifting and powerlifting records and some studies hint that maximal strength may not be the first factor that is affected by aging. It seems that rate of force development – and thus speed in the weightlifting movements – will be affected more and sooner. For this reason, it is important to put some emphasis on speed training for masters weightlifters. This might be in the form of plyometrics or lights pulls and squats. Since masters weightlifters are likely to take longer to recover from sets within a training session, it may be a good idea to reduce your expectations of how much work can be done in a certain time. The number of sessions per week is likely to be lower on average than it would be for younger athletes.

While all of these things are worth considering when you are coaching masters weightlifters, it is important to remember that everyone is different – you may come across a weightlifter in their forties who is better conditioned than the younger weightlifters you work with and can handle an even greater workload.

MASTERS COMPETITION

Weightlifting competitions for those who are aged thirty-five and over work very much like any other weightlifting competition but with the significant difference that every competitor will have an age category as well as a weight category. The good news is that this dramatically increases the number of categories, creating more opportunities to win medals and set records!

The applicable age category is calculated using the year of birth of the athlete – in other words, your age for this year is the age you will be on the 31st December. So, any time in the year when someone will turn 35, they are eligible to compete as a masters athlete. Each category covers five years of age and has a letter to specify the sex of the athlete:

Age at 31st December	Men's Category	Women's Category
35–39	M35	W35
40–44	M40	W40
45–49	M45	W45
50–54	M50	W50
55–59	M55	W55
60–64	M60	W60
65–69	M65	W65
70–74	M70	W70
75–79	M75	W75
80+	M80	W80

Masters weightlifters will enter a competition in a specific weight and age category. So, if I was a -89 M40, I would be aged 40 to 44 and would need to weigh in under 89 kg.
As well as prizes in specific weight/age category combinations, best lifter prizes are also often presented for age groups or overall. For age group prizes, the well-known Sinclair calculation is usually used to create an even playing field between weight categories. For overall prizes, an extra adjustment, called the Malone-Meltzer coefficient, is applied to account for age. The overall score is then usually known as Sinclair Malone-Meltzer or SMM – you will often see a column for this on scoreboards at masters competitions.

Masters competitions, at least at the lower levels, often have a different, slightly less competitive atmosphere than senior competitions. There is usually a greater sense of community and of a shared resolve to achieve goals. But make no mistake, when national or international medals are at stake, masters weightlifters will compete just as hard as their younger counterparts!

Masters competitions tend to run in parallel to the system of senior competitions, with matching regional, national and international competitions to qualify for. At the international level, the competitions are recognised by the IWF and continental federations but are organised by separate organisations. Attending masters competitions can be an inspirational experience in itself. Seeing people aged eighty and beyond get up on stage and perform the competition weightlifting movements really shows that we do not need allow aging to limit what we can do.

SUMMARY

In this paper, we have looked at why masters weightlifters are an attractive market for any weightlifting club or gym and how to create an environment that will attract them and convince them to become long-term, loyal members. We have also discussed some of the challenges that affect older athletes to a greater degree than with younger weightlifters, along with some strategies for coping with these problems.

The key things to keep in mind about masters weightlifters are:

- **Longer histories may hold more things you need to know about, positive and negative**
- **Biological age is important but training age is even more so**
- **Progress will probably be slower**
- **Mobility is more likely to be a problem**
- **You can use power or even split variations**
- **Speed training is important**
- **Every athlete is different**

You should now have a clear idea of why masters athletes are important and how to adapt your coaching to suit them.

REFERENCES

Bartke, A. (2008). Growth hormone and aging: A challenging controversy. Clinical Interventions in Aging, 3(4), 659–665.

Bellumori, M., Jaric, S., & Knight, C. (2013). Age-Related Decline in the Rate of Force Development Scaling Factor. Motor Control, 17, 370–381. https://doi.org/10.1123/mcj.17.4.370

Boss, G. R., & Seegmiller, J. E. (1981). Age-Related Physiological Changes and Their Clinical Significance. Western Journal of Medicine, 135(6), 434–440.

Canepari, M., Pellegrino, M. A., D'Antona, G., & Bottinelli, R. (2010). Single muscle fiber properties in aging and disuse. Scandinavian Journal of Medicine & Science in Sports, 20(1), 10–19. https://doi.org/10.1111/j.1600-0838.2009.00965.x

Dalton, B. H., Power, G. A., Vandervoort, A. A., & Rice, C. L. (2012). The age-related slowing of voluntary shortening velocity exacerbates power loss during repeated fast knee extensions. Experimental Gerontology, 47(1), 85–92. https://doi.org/10.1016/j.exger.2011.10.010

Doering, T. M., Reaburn, P. R., Borges, N. R., Cox, G. R., & Jenkins, D. G. (2017). The Effect of Higher Than Recommended Protein Feedings Post-Exercise on Recovery Following Downhill Running in Masters Triathletes. International Journal of Sport Nutrition and Exercise Metabolism, 27(1), 76–82. https://doi.org/10.1123/ijsnem.2016-0079

Easthope, C. S., Hausswirth, C., Louis, J., Lepers, R., Vercruyssen, F., & Brisswalter, J. (2010). Effects of a trail running competition on muscular performance and efficiency in well-trained young and master athletes. European Journal of Applied Physiology, 110(6), 1107–1116. https://doi.org/10.1007/s00421-010-1597-1

Keller, K., & Engelhardt, M. (2014). Strength and muscle mass loss with aging process. Age and strength loss. Muscles, Ligaments and Tendons Journal, 3(4), 346–350.

Kelsey, T. W., Li, L. Q., Mitchell, R. T., Whelan, A., Anderson, R. A., & Wallace, W. H. B. (2014). A Validated Age-Related Normative Model for Male Total Testosterone Shows Increasing Variance but No Decline after Age 40 Years. PLoS ONE, 9(10). https://doi.org/10.1371/journal.pone.0109346

Murman, D. L. (2015). The Impact of Age on Cognition. Seminars in Hearing, 36(3), 111–121. https://doi.org/10.1055/s-0035-1555115

Power, G. A., Minozzo, F. C., Spendiff, S., Filion, M.-E., Konokhova, Y., Purves-Smith, M. F., ... Rassier, D. E. (2015). Reduction in single muscle fiber rate of force development with aging is not attenuated in world class older masters athletes. American Journal of Physiology-Cell Physiology, 310(4), C318–C327. https://doi.org/10.1152/ajpcell.00289.2015

Roach, K. E., & Miles, T. P. (1991). Normal Hip and Knee Active Range of Motion: The Relationship to Age. Physical Therapy, 71(9), 656–665. https://doi.org/10.1093/ptj/71.9.656

UK Government Exercise Advice Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213740/dh_128145.pdf

ELEIKO PAPERS

Find all of our Eleiko Papers at eleiko.com/education/resources.

THE PERFECT SETUP

FOLLOW THE FUTURE OF STRENGTH AT ELEIKO.COM

ELEIKO

RAISE THE BAR

Spanish resumenes

EFECTOS DE LA INSATISFACCIÓN CORPORAL Y DE LA ANSIEDAD RASGO EN LA AUTOESTIMA DE JÓVENES LEVANTADORES DE PESAS.
Khizer Hayat
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 4-13
Este estudio fue llevado a cabo en jóvenes levantadores de pesas de Pakistán. Según los autores, la autopercepción, la inquietud y la confianza son los componentes que influyen en la técnica de los levantadores de pesas. Esta investigación permitirá evaluar la contribución de los tres factores antes mencionados en la mejora de la técnica de los levantadores de pesas.

REALANALYZER HD – UN SOFTWARE DE SEGUIMIENTO DE LA BARRA DE PESAS EN TIEMPO REAL PARA LA HALTEROFILIA.
Ingo Sandau, Holger Jentsch, Michael Bunk
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 14-23
El análisis del movimiento en los deportes es un paso necesario para alcanzar un resultado de alto nivel. En la halterofilia, el análisis del movimiento de la barra es la referencia para la calificación de la técnica deportiva y de las capacidades físicas del atleta. Existe la posibilidad de utilizar varios sistemas para medir el movimiento de la barra (trayectoria, velocidad, aceleración). La mayoría de los análisis se basan en mediciones extraídas de grabaciones en vídeo (videometría). Este es el sistema más utilizado especialmente en la halterofilia. El mayor inconveniente de este sistema de medición es la necesidad de controlar la barra en cada fotograma de la imagen de vídeo. Dado que el seguimiento manual lleva mucho tiempo, los investigadores del Instituto de Ciencias Aplicadas de Entrenamiento (Leipzig, Alemania) han desarrollado un software a medida para la halterofilia que controla automáticamente la barra en las grabaciones de vídeo. En este documento presentamos el software Realanalyzer HD para el seguimiento de la barra en la halterofilia. Este sistema mide el movimiento de la barra con una enorme precisión siempre que se observen las normas de configuración. Asimismo explicamos los parámetros medidos y ofrecemos consejos para la interpretación de los datos.

ELOGIAR EL LÍMITE PARA ALCANZAR LA VICTORIA.
Antonio Urso
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 24-29
El autor aborda un tema de enorme interés: el sentido del límite como premisa fundamental para la definición de una óptima actuación en todos los aspectos de la vida y en cada una de las experiencias humanas. Según el autor, "el límite es en realidad la condición a partir de la cual se entrelazan y se entretejen las mayores conquistas del género humano".

TRETAS, BATES DE BÉISBOL Y PANTORRILLAS: CONSIDERACIONES SOBRE LA POSICIÓN DE PARTIDA HÚNGARA.
Andrew Charniga
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 30-39
Interesantes reflexiones sobre las diferencias entre la llamada posición de partida clásica y la posición de partida húngara en los gestos del envión y la arrancada en la halterofilia. El autor identifica los puntos fuertes y los puntos débiles de las diferentes técnicas, especialmente desde el punto de vista biomecánico, e intenta demostrar las razones del uso actual, por parte de un gran número de atletas asiáticos, de la posición de partida húngara.

LA MUJER Y EL DEPORTE.
Thompson T., Steffert T., Ros T., Leach J., Gruzelier J., Ivaldi M.
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 40-57
Los autores presentan un interesante análisis de las posibilidades de aplicación de la electroencefalografía en el ámbito deportivo, lo que ya se ha realizado y probado, las perspectivas, los pros y los contras, los ámbitos que deben ser perfeccionados para obtener unos resultados mejores y más previsibles. Se trata de un texto de considerable valor por su análisis de la situación de una metodología enormemente interesante.

FRONTERAS DE LOS CONOCIMIENTOS. CONCEPTOS DE MECANOBIOLOGÍA APLICADOS AL ENTRENAMIENTO DE LA FUERZA.
Donato Formicola
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 58-69
El objetivo de este artículo es la descripción de la adaptación anatómica al entrenamiento con las sobrecargas como fenómeno mecanobiológico. La sucesión organizada de las cargas mecánicas que constituyen un programa de entrenamiento, hace que todo el organismo se adapte anatómicamente solo cuando este activa los procesos de memoria miocelular. Esta memoria se guarda en el patrimonio genético de los mionúcleos, que son replicados con el entrenamiento de alta intensidad. Cuantos más núcleos tenga una célula muscular, más capaz es esta de hipertrofiar cada vez que le llega una fuerza externa. Este fenómeno mecanobiológico recursivo, definido de histéresis cíclica, es la base de los procesos de detraining y retraining. Por consiguiente, en la programación de las cargas de trabajo que contemplan una adaptación anatómica eficaz, deben considerarse los procesos de memoria muscular e histéresis cíclica para evitar la aparición, durante la práctica, de algunas criticidades significativas que podrían aumentar el riesgo de no alcanzar los resultados esperados.

LEVANTADORES DE PESAS EXPERTOS.
Eleiko
SM (ing), nº 13, año V, mayo-agosto 2019, págs. 70-75
En este documento abordamos porqué los levantadores de pesas expertos son un mercado atractivo para los clubes de halterofilia o gimnasios y cómo crear un entorno que los atraiga y convenza para convertirse en miembros fieles y de larga duración. También hemos debatido algunos de los retos que afectan mucho más a los deportistas de mayor edad que a los levantadores de pesas más jóvenes, además de algunas estrategias para afrontar estos problemas. Las consideraciones clave sobre los levantadores de pesas expertos son:

- Las historias más largas pueden suponer más cosas que es necesario conocer, tanto positivas como negativas
- La edad biológica es importante pero la edad de entrenamiento lo es más
- Los avances serán probablemente más lentos
- Es muy probable que la movilidad sea un problema
- Pueden utilizarse variaciones en la fuerza e incluso variaciones en el split
- El entrenamiento de la velocidad es importante
- Cada deportista es diferente

Ahora debería tener una idea clara de la importancia de los deportistas expertos y cómo adaptar su preparación para ellos.

Russian resumenes

ВЛИЯНИЕ «НЕУДОВЛЕТВОРЕНИЯ» ОРГАНИЗМА И ТРЕВОГИ НА САМОВОСПРИЯТИЕ У МОЛОДЫХ ТЯЖЁЛОАТЛЕТОВ
Khizer Hayat
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 4-13
Данное исследование было проведено на молодых тяжёлоатлетах Пакистана. По мнению авторов, самовосприятие, беспокойство и уверенность это те компоненты которые влияют на выполнение работы штангистов. Это исследование может помочь оценить как вышеупомянутые факторы могут улучшить выполнение работы тяжёлоатлетов.

REALANALYZER HD (АНАЛИЗАТОР HD В РЕАЛЬНОЕ ВРЕМЯ)
ПРОГРАММА ДЛЯ МОНИТОРИНГА ШТАНГИ В РЕАЛЬНОЕ ВРЕМЯ ВО ВРЕМЯ ТЯЖЁЛОАТЛЕТИЧЕСКИХ ДВИЖЕНИЙ
Ingo Sandau, Holger Jentsch, Michael Bunk
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 14-23
Анализ движений это необходимый шаг к достижению высоких спортивных результатов. В тяжёлой атлетике анилиз движений штанги является «золотым стандартом» для оценки спортивной техники и физичеких способностей спортсмена. Для оценки движения штанги (траектории, скорости, ускорения) могут испрользоваться различные системы. Большинство анализов основано на измерениях с помощью видеозаписи (видеометрии). Этот метод используется особенно часто в тяжёлой атлетике. Основным недостатком этого метода является то что движение штанги необходимо отслеживать в каждом кадре видеоизображения. Ручное отслеживание занимает очень много времени, таким образом исследователи Института прикладной науки (Лейпциг, Германия) разработали специальное программное обеспечение для тяжёлой атлетики которое позволяет реализовать автоматическое отслеживание штанги при видеозаписи. В данной статье представлена компьютерная программа Realanalyzer HD используемая для анализа движения штанги в тяжёлой атлетике. Эта система в состоянии измерять с высокой точностью движение штанги при условии соблюдения стандартов настройки. Кроме того, предоставляются дополнительное объяснение измеренных параметров и «подсказки» для интерпретации полученных данных.

ВАЖНОСТЬ ПОНЯТИЯ «ПРЕДЕЛ» ДЛЯ ПОСТРОЕНИЯ ПОБЕДЫ
Antonio Urso
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 24-29
Автор рассматривает тему представляющую большой интерес: обладание чувством предела как фундаментальной предпосылки для определения оптимальной производительности во всех сферах и в любых ситуациях жизни. По мнению автора, «предел это на самом деле условие предопределяющее любые величайшие достижения человечества».на выполнение работы штангистов. Это исследование может помочь оценить как вышеупомянутые факторы могут улучшить выполнение работы тяжёлоатлетов.

ЛОВУШКИ, БЕЙСБОЛЬНЫЕ БИТЫ И ИКРЫ: СООБРАЖЕНИЯ О “ВЕНГЕРСКОМ НАЧАЛЕ ДВИЖЕНИЯ”
Andrew Charniga
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 30-39
В статье представлены интересные размышления о различиях между так называемыми “классическим” и “венгерским” началом в упражнениях толчок и рывок тяжёлой атлетики. Автор описывает сильные и слабые стороны этих двух техник, особенно с биомеханической точки зрения, и пытается определить причины которые в настоящие дни привлекают большое число азиатских спортсменов использовать так называемое «венгерское» начало.

ПРИМЕНЕНИЕ ЭЛЕКТРОЭНЦЕФАЛОГРАФИИ В СПОРТЕ (ПЕРВАЯ ЧАСТЬ)
Thompson T, Steffert T, Ros T, Leach J, Gruzelier J, Ivaldi M
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 40-57
Авторы представляют интересный обзор возможностей применения электроэнцефалографии в области спорта: то что пытались сделать и то уже было сделано, перспективы, плюсы и минусы, области в которых можно что то усовершенствовать для достижения всё более высоких и надёжных результатов. Статья имеет очень большую ценность потому что наконец то анализирует очень интересную методику.

ГРАНИЦЫ ЗНАНИЙ. ПОНЯТИЯ “МЕХАНИЧЕСКОЙ БИОЛОГИИ” В ПРИМЕНЕНИИ К СИЛОВОЙ ТРЕНИРОВКЕ.
Donato Formicola
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 58-69
Цель этой статьи заключается в описании анатомической адаптации к тренировке с сопротивлениями (отягощениями) как механико-биологического феномена. Организованная последованность использования механических нагрузок, составляющих тренировочную программу, приводит к анатомической адаптации всего организма только тогда когда «запускает» процессы миоклеточной памяти. Подобная память сохраняется в генетическом наследии миоядер, которые воспроизводятся при высокоинтенсивной тренировке. Чем больше ядер имеет мышечная клетка, тем больше она способна к гипертрофии, всякий раз когда воздействует внешняя сила. Это рекурсивное механо-биологическое явление, определённое как «циклический гистерезис (istèresi)», лежит в основе процессов «детренинга» и «ретренинга». Следовательно, при программировании тренировочных нагрузок направленных на эффективную анатомическую адаптацию, необходимо учитывать процессы мышечной памяти и «циклический гистерезис», чтобы избежать в процессе работы некоторые значительные критические моменты, которые могут повысить риск не достигнуть ожидаемые результаты.

МАСТЕРА ТЯЖЁЛОЙ АТЛЕТИКИ. ЭЛЕИКО (ELEIKO)
SM (Eng), nº 13, anno V, maggio-agosto 2019, pp . 70-75
В этой статье рассматривается почему мастера тяжёлой атлетики являются привлекательным «рыночным объектом» для любого клуба или спортзала и как создать среду которая бы позволила убедить их быть долгосрочными и лояльными членами и сотрудниками. Обсуждаются так же некоторые проблемы, которые касаются в основном высоковозрастных спортсменов по сравнению с более молодыми тажёлоатлетами, а так же некоторые стратегии позволяющие преодолеть эти проблемы. Представлены ключевые пункты которые надо иметь в виду когда речь идёт о мастерах тяжёлой атлетики:
1.более длительная история которая может содержать больше вещей о которых надо знать, положительных и отрицательных;
2.биологический возраст важен, но тренировочный возраст тем более;
3.прогресс, вероятно, будет медленнее;
4.гибкость, скорее всего, будет проблемой;
5.можно использовать мощность ли же возможные варианты;
6.важна скоростная тренировка
7.каждый спортсмен индивидуален.
Таким образом складывается чёткое представление о важности спорсменов мастеров и о том как адаптировать подход к их процессу тренировки.

S CIENTIFIC
MAGAZINE

THE OFFICIAL JOURNAL OF THE EUROPEAN
WEIGHTLIFTING FEDERATION