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The effect of repetition ranges on maximal strength and hypertrophy.

A pilot study of an 8-weeks specified strength-training program.

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Abstract:

This study investigated the effects of repetition ranges with modified intensity and volume on muscle mass and maximal strength. Fourteen healthy athletes from a team sport club were randomly assigned to either a low repetitions or high repetitions group. The low repetitions (LR) group performed 3 sets of 3-5 reps at 90-95% one repetition maximum (1RM) and high repetitions (HR) group performed 5 sets of 10-12 reps at 60-70% 1RM in specific strength training exercises for an eight weeks period. Muscle strength and muscle thickness measures were taken at baseline, four weeks and after the eight weeks of training. Results show LR gained better maximal strength than HR group after the eight weeks of training in both the flat bench press and the squat test($p=0.0201$ and $p=0.0165$ respectively). As for muscle thickness, outcomes of the quadriceps cross section thickness were almost identical between the two groups. There was no significant difference at 4 or 8 weeks ($p=0.8776$ and $p=0.9335$ respectively). Our findings suggest performing low reps with high intensity (load) is more beneficial for gaining maximal strength and muscle mass in short training cycles. Future researches are needed to substantiate these findings in a larger cohort.

Key words: repetition range, maximal strength, muscle hypertrophy.

الملخص:

بحثت هذه الدراسة في أثر مجموعة التكرارات مع درجات مختلفة للشدة والحجم على تضخم العضلات وصفة القوة القصوى. تم اختيار أربعة عشر (14) رياضي يمارسون الرياضات الجماعية وتقسيمهم بطريقة عشوائية إلى مجموعتين. مجموعة ذات عدد تكرارات منخفض وشدة حمل عالية سمي بـ LR (3 مجموعات، 3-5 تكرارات، شدة حمل: 90 – 95%) ومجموعة ذات عدد تكرارات مرتفع وشدة حمل متوسطة سمي بـ HR (5 مجوع تكرارات، 10-12 تكرار، شدة حمل: 60-70%). مدة الدراسة كانت 8 أسابيع تم خلالها قياس القوة القصوى وقطر عضلة الفخذ (quadriceps) عند البداية، بعد أربعة أسابيع وبعد نهاية الدراسة. النتائج النهائية تظهر أن LR لدية تطور ملحوظ في صفة القوة القصوى مقارنة بـ HR في كل تمرين القرفصاء وتمرين عضلة الصدر ($p=0.0201$ و $p=0.0165$ على التوالي). أما بخصوص نسبة نمو العضلات، كانت نتائج قطر عضلة الفخذ متشابهة تقريبا بين المجموعتين.

المعطيات المستوحاة من دراستنا هذه تنصح بأداء تمارين تقوية العضلات ذات تكرارات قليلة وشدة عالية لتطوير صفة القوة القصوى وزيادة حجم العضلة في الدورات التدريبية الصغرى. هذه المعطيات بحاجة إلى دراسات مستقبلية تثبت ما توصلنا إليه على عينة أكبر ومدة زمنية أطول.

الكلمات المفتاحية: عدد التكرارات، القوة القصوى، تضخم العضلات.

Résumé:

Cette étude a examiné les effets des plages de répétition avec une intensité et un volume modifiés sur l'hypertrophie et la force maximale. Quatorze athlètes qui pratiquent un sport collectif ont été assignés au hasard à un groupe de répétitions basses ou élevées. Un groupe avec nombre des répétitions minimal (3-5) et intensité élevé (90-95%) nommée LR, et un groupe avec nombre des répétitions élevé (10-12) et intensité modern (60-70%) dans des exercices de musculation spécifiques pendant huit semaines. Les mesures de force et d'épaisseur musculaires ont été mesurées au départ, quatre semaines et après les huit semaines d'entraînement. Les résultats montrent que la LR a acquis une meilleure force maximale que le groupe HR après huit semaines d'entraînement dans les deux tests de presse à banc plat et squat ($p=0.0201$ et $p=0.0165$ respectivement). En ce qui concerne l'épaisseur du muscle, les résultats de l'épaisseur de la section transversale du quadriceps étaient presque identiques entre les deux groupes. Il n'y avait pas de différence significative à 4 ou 8 semaines ($p=0.8776$ et $p=0.9335$ respectivement). Nos résultats suggèrent que réaliser de petites répétitions avec une intensité élevée (charge) est plus bénéfique pour obtenir une force et une masse musculaire maximales lors de cycles d'entraînement courts. Des futures recherches sont nécessaires pour corroborer ces résultats dans une cohorte plus large.

Mots clés : nombre des répétitions, force maximal, l'hypertrophie.

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Dedication:

This humble work is dedicated to my parents and my young sister whose constant support, understanding and encouragement allowed me to accomplish this goal. To all my friends who provided much appreciated thoughts and ideas in order to complete this work.

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Abbreviations

Abbreviation	Explanation
HR	high repetitions
LR	low repetitions
RT	resistance training
ROM	Range of Motion
1RM	1 repetition maximum
VL	volume load
MT	muscle thickness
DOMS	delayed onset muscle soreness
MPS	Muscle protein synthesis
SD	standard deviation
SS	statistically significant
NSS	not statistically significant

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Chapter one: methodology.

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Introduction.

Most literature defines strength as the ability to produce force by muscular contraction. Newton's first law of motion states that an object will remain at rest unless a force is placed upon it. For instance. This law refers to inertia, which is essentially an object's reluctance to move.

Strength is considered one of the important elements of training, wherever you were an athlete aiming to get better performance and results or seeking better shape or a healthy cause, you will need to train and develop your strength at some point. Methods of strength training have developed over the years and at some point; you will be introduced to bodybuilding.

Strength is referred to as having two divisions: structural and functional (Verkhoshansky & Stiff, 2009). Structural training is the process of affecting the musculature itself, such as an increase in actin and myosin filaments as a result of heavy strength training. Generally, structural training serves the purpose of inducing hypertrophy, whether it is myofibrillar, where an increase in the density of fibers is evident, or sarcoplasmic, where cellular cytoplasm increases (Martini, Ober, Bartholomew, & Nath, 2011). Functional adaptations are the products of training that are then expressed during sports performance: for instance, strength-speed. While it may seem obvious that understanding the purpose of training is imperative before programming, there is a distinct difference between the two in terms of the variables of load, sets, reps, rest, and variation.

Strength training is paramount in the development of athletes, but it must consist of more than just lifting weights without a specific purpose or plan. In fact, the purpose of any strength training method should be to prepare athletes for competition, the ideal test of their skills, knowledge, and psychological readiness. To achieve the best results, athletes need to be exposed to a periodization program or sport and phase specific variations in training (Bompa & Haff, Periodization Theroy and Methodology of Training, 2009). Resistance training is a physical activity that is commonly used to develop muscle strength and stimulate muscle hypertrophy (anatomical adaptation, hypertrophy and maximal strength). Maximizing these training adaptations involves the appropriate manipulation of resistance training variables (Kraemer & Ratamess, 2004). Arguably, one of the most critical variables influencing the effectiveness of resistance training on muscle strength and

hypertrophy is volume (Schoenfled, Ogborn, & Krieger, 2017) and resistance load (intensity).

While some trainers believe that to achieve maximal strength they need to train hypertrophy first, some studies showed that having more muscle mass does not mean having more strength (Schoenfeld B. J., et al., 2019; Dankel, et al., 2016). In fact, hypertrophy relies more on volume than intensity. A recent study (Schoenfeld B. J., et al., 2019) done on thirty four healthy resistance training men comparing low volume resistance training to moderate and high volume, found out that while all groups showed significant preintervention to postintervention in strength and endurance, results favorited the group with high volume.

Three systematic reviews and meta-analyses have provided some interesting insights into the effects of set number on muscle strength and hypertrophy. Krieger found that 40% greater muscle strength and hypertrophy gains could be achieved with 2–3 sets compared to a single set per exercise (Krieger, 2010). Furthermore, Krieger showed a dose-response relationship with greater muscle strength and hypertrophy gains with an increased number of sets (Krieger, 2009), up to approximately 4–6 sets, where no further gains were observed. These findings support the recommended set range for advance trainers from the resistance training guidelines. In addition, Schoenfeld et al. analyzed the impact of the total number of weekly sets per muscle group that was suggested to be a more relevant marker of training volume (Schoenfeld, Krieger, & Ogborn, 2017). The results of this review and meta-analysis indicated a dose-response relationship between weekly resistance training volume and muscle mass, and it was concluded that at least 10 weekly sets per muscle group is necessary to maximize muscle mass.

2- Problematic:

While these studies were done on more advanced athletes or participant that have some experience in resistance training, we could not find recent study done on athletes that just started strength training.

A recent pilot study published in 2018 done on participants with a 1year experience in strength training, studied the effects of a 12 weeks modified german training volume program on muscle strength and hypertrophy (Hackett, et al., 2018). Twelve healthy males

were randomly assigned to either a 5-SET or 10-SET of 10 repetitions at 60–80% one-repetition maximum (1RM).Results showed no significant differences between the two groups and suggested performing 5 sets per exercise does not promote greater gains in muscle strength and hypertrophy.

Our study has been done on athletes that have been training for years in team sports which make us conclude they have some sort of basic strength. The question we based our study on is:

- **Should we train hypertrophy first in order to pass to maximal strength training or is it possible to train hypertrophy throughout maximal strength training?**
- **Does performing a low range of sets and repetitions increase muscle mass gains?**
- **How does intensity and weekly volume training effect hypertrophy and maximal strength?**

3- Hypothesis:

The aim of our study was to investigate to effect of a resistance training program with low sets and high intensity vs high sets and low intensity for 8 weeks. We based our study on two exercises (flat bench press and squat) which are the only modified exercises between the two groups. All the other exercises stayed the same, both groups had the same volume and the same effort produced for each exercise.

According to the recent studies, hypertrophy and volume have a dose-response relationship and maximal strength development relies on high intensity. Since our participants are new to weightlifting, we suggest the following:

- **all subjects will gain some level on strength but favoring the group with high intensity and low repetitions (LR) and a gain in muscle mass favoring the group with high sets (HR).**

4- Goals:

The main goal of this thesis is to investigate whether training maximal strength can have the same muscle mass gains as training for hypertrophy; which could help trainers and coaches with their strength training periodization.

5- Key words definitions:

5-1- Maximal strength: The highest level of muscle force that can be produced, maximum strength is the ability of a muscle or specific group of muscles to recruit and engage all motor units to generate maximal tension against an external resistance. Requires high levels of neuromuscular efficiency to enhance both intra- and intermuscular coordination. (Stoppani, Encyclopedia of Muscle & Strength, 2014).

5-2- Hypertrophy:

Muscle hypertrophy is a term for the growth and increase of the size of muscle cells. The most common type of muscular hypertrophy occurs as a result of physical exercise such as weightlifting, and the term is often associated with weight training. According to the medical dictionary, hypertrophy is a condition involving enlargement of muscles. May be induced pathologically or non-pathologically, as in weight training.

5-3- Repetition range:

Trainers, athletes and exercise professionals refer to Repetitions as reps, reps and sets are units of measurement that provide structure and organization to the workout plan.

6- Similar studies:

A 2015 study by Gerlad et al. investigated the effect of training volume and intensity on improvements in muscular strength and size in resistance-trained men; the study tried to compare the effect of high-volume versus high-intensity resistance training. The high volume group had an intensity of 70% of 1RM and 10-12 reps and 1min rest intervals, while the high-intensity group did the exercises at 90% with 3-5 reps and a 3min rest intervals. The study lasted 10 weeks and found that high-intensity resistance training stimulates greater improvements in some measures of strength and hypertrophy in resistance-trained men during a short-term training period (Mangine, et al., 2015).

A2015 study by Brad Schoenfeld et al. investigated the differential effects of heavy versus moderate loads on measures of strength and hypertrophy in resistance-trained men. The purpose of this study was to evaluate muscular adaptations between heavy and moderate load resistance training with all other variables controlled between conditions. The heavy loads group have range of 2-4 reps per set and the moderate loads groups a 8-

12 reps. The findings indicate that heavy load training is superior for maximal strength goals while moderate load training is more suited to hypertrophy-related goals when an equal number of sets are performed between conditions.

A 2017 ayatematic review and meta-analysis by Schoenfeld et al. about strength and hypertrophy adaptations between low vs high load resistance training. The findings indicate that maximal strength benefits are obtained from the use of heavy loads while muscle hypertrophy can be equally achieved across a spectrum of loading ranges.

A 2017 study by Charles Ricardo Lopes et al. about the effect of different resistance training load schemes on strength and body composition in trained men tried to evaluate the impact of moderate load (10RM) and low load (20RM) resistance training schemes on maximal strength and body composition. The findings suggest both moderate-load and low-load resistance training schemes, similar for the total load lifted, induced a similar improvement in maximal strength and body composition in resistance-trained men.

Another study by Schoenfeld et al. published in 2019 titled:'Resistance training volume enhances muscle hypertrophy but not strength in trained men' evaluated muscular adaptations between low, moderate and high volume resistance training protocols in resistance trained men. Results showed significant preintervention to postintervention increases in strength and endurance in all groups, with no significant between-group differences. Alternatively, while all groups increased muscle size in most of the measured sites from preintervention to postintervention, significant increases favoring the higher-volume conditions were seen for the elbow flexors, mid-thigh, and lateral thigh.

Part One:
theoretical part.

Chapter One: Strength Training and Hypertrophy.

I- Maximal Strength:

1- Definition of maximal strength:

Maximal strength is the ability to exert force upon an external object. This attribute is typically measured by a 1 repetition maximum (1RM) on a barbell based exercise such as a squat or press. Maximal strength is essentially a measure of how much force your body can exert.

Maximal strength training is resistance training that uses high loads and few repetitions. Using this method, increases in muscle strength occur through neural adaptations rather than via an increase in the size of the muscle (Schoenfeld B. J., et al., 2019).

2- Variables that contribute to maximal strength improvement:

Resistance training program variables can be manipulated to specifically optimize maximum strength. After deciding on the exercises appropriate for the sport, the main variables to consider are training intensity (load) and volume. The other factors that are related to intensity are loading form, training to failure, speed of contraction, psychological factors, inter-set recovery, order of exercise, and number of sessions per day. Repetitions per set, sets per session, and training frequency together constitute training volume. In general, maximum strength is best developed with 1–6 repetition maximum loads, a combination of concentric and eccentric muscle actions, 3–6 maximal sets per session, training to failure for limited periods, long interset recovery time, 3–5 days of training per week, and dividing the day's training into 2 sessions. Variation of the volume and intensity in the course of a training cycle will further enhance strength gains. The increase in maximum strength is effected by neural, hormonal, and muscular adaptations. Concurrent strength and endurance training, as well as combination strength and power training (Tan, 1999).

When athletes train, they are exposed to a series of stimulations that alter their physiological status. These physiological responses can include acute metabolic, hormonal, cardiovascular, neuromuscular, and cell signaling alterations. These physiological responses to training are mitigated by the volume, intensity, frequency, and type of training undertaken by the athlete. The greater the volume, intensity, or duration of training, the

greater the magnitude of the physiological responses to training (Bompa & Haff, Periodization: Theory and Methodology of Training, 2009).

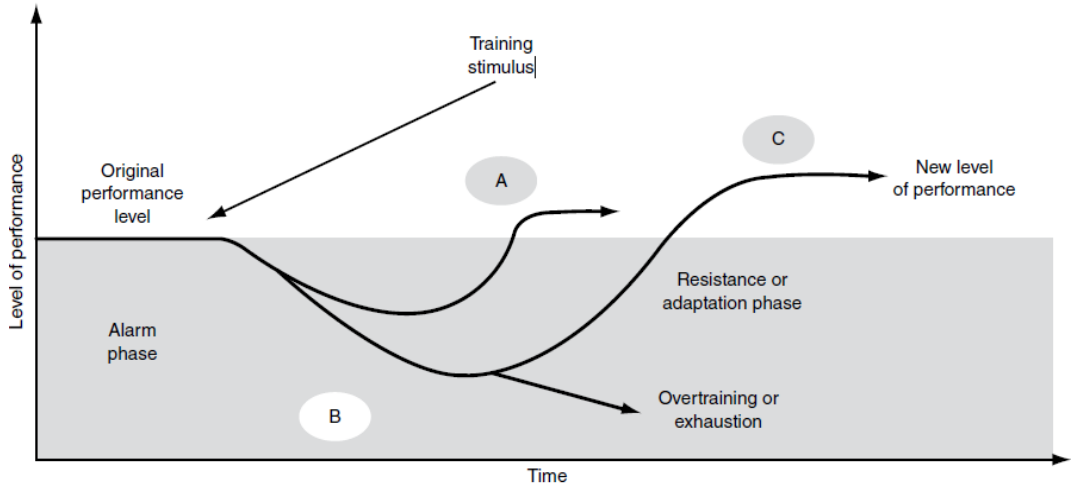

Figure N°01: Illustration of Selye's general adaptation syndrome theory. A = typical training; B = overtraining; C = overreaching or supercompensation (Fry A. C., 1997).

2-1- intensity:

Training intensity is one of the most important variables to consider when designing a resistance training program that targets maximum strength. It is reflected by the load or resistance used. Absolute intensity is the load lifted per repetition whereas relative intensity is the percentage of the 1RM lifted (Stone, Chandler, Conley, Kramer, & Stone, 1996).

The role of a high training intensity is to increase neural activation; peak electromyographic activity in muscles, which reflects the level of neural activity, in-creases with increasing load (Newton, et al., 1997). Likewise, the integrated electromyographic activity has been shown to increase during high-intensity training (.80% of 1RM and eccentric contractions at 100–120% of 1RM) and decrease during low-intensity training and detraining (Häkkinen, Komi, & Alen, 1985). Neural activation serves not only as a stimulus for strength gains, but it is also an adaptation to strength training. As a stimulus, increased neural activation contributes to strength gains during the first 4 weeks of the training period, whereas muscle hypertrophy plays a bigger role during the later part of the training period.

High training intensities evoke a postexercise increase in testosterone release as well as an increase in human growth hormone. The elevation of these two anabolic hormones in the serum, coupled with a decrease in serum cortisol levels, brings about an anabolic environment that encourages hypertrophy and strength gains (Kraemer, et al., 1995).

2-1-1- Optimal load:

We explained previously load forms that muscular action during exercise can be concentric, eccentric, or isometric (in Core Concepts section). The design of training regimens with the goal of improving the maximal strength is already well established in the literature (Brown & Weir, 2001). Studies suggest that in order to achieve maximum strength, three strategies need to be followed:

a- The use of optimal loads, represented by the load where the highest power output is achieved.

b- The use of heavier loads—normally above 60 up to 80% of 1 repetition maximum (1RM), which is represented by loads that would activate high activation threshold motor units.

c- A mixed approach in which a variety of loads are used to optimize the power output.

Previous studies have demonstrated that the optimal load for the peak power output (PPO) during the bench press throw ranged from 30 to 70% of 1RM (Cronin, McNair, & Marshall, 2001). However, the optimal load can be affected by many factors, such as the athletic level, maximal strength, and types of exercise. Regarding the level of the athlete and maximal strength, Baker reported that professional players were significantly stronger and more powerful than college-aged rugby league players (Baker, 2001). Another issue is the types of exercise used, and previous studies demonstrated that the bench press throw condition produced a significantly higher peak power compared with the bench press, which included holding onto the bar at the end of the concentric phase (Da Silva, De Moura Simim, Marocolo, Franchini, & Ribeiro da Mota, 2015).

Although not all of the recent studies equated training volume while investigating the intensity, the volumes used by the various experimental groups were not on either extreme,

making the results slightly more reliable. These studies demonstrate convincingly that heavy loads of 70–120% of 1RM, or 1–6 RMs, are the most effective in enhancing maximum strength. This is also true in the maintenance of maximum strength (Benedict, 1999).

When training for maximum strength, the loading should vary within the 1–6RM zone. Although the efficacy of variations in intensity and volume over training periods (periodization) has been investigated, there is little conclusive evidence to indicate if the variation of loads from set to set as described above is effective or necessary (Benedict, 1999).

2-1-2- Training to failure:

It is important to put all resistance training sets to maximal in order to enhance maximum strength, this higher load ensures that high level of neural activation or drive is used to stimulate the muscles. Using the proper technique, the athlete should attempt to complete as many repetitions are possible to provoke the muscle stimulation. This type of training relies on prescribing either to load alone where the athlete does the maximum repetitions possible, or the repetition alone should be prescribed.

Considering that evidence supporting the long-term benefits of training to failure is still equivocal, training to failure should be limited to short periods only to reduce the risk of overtraining, overuse injuries, and possibly negative psychological conditioning (Benedict, 1999).

2-1-3- speed of contraction:

For a given resistance, a high speed of contraction will necessitate a higher degree of motor unit recruitment, resulting in greater strength gains. A study comprising 2 groups of untrained men, one performing the contractions as fast as possible (i.e., making a maximal effort) to lift the bar during a half-squat, and the other lifting the barbell in a slow and controlled manner, showed that both groups had significant but similar gains in 1RM squat after 8 weeks of training (Young & Bibly, 1993). Unfortunately, the IEMG (integrated electromyography) was not measured during the study to confirm if the neural activation was indeed different for both groups. The authors suggested that perhaps the slow-

contracting group made up for the lower neural activation with a more prolonged period of muscle tension, hence a longer stimulus.

2-1-4- Order of exercise:

Exercise order refers to a sequence of resistance exercises performed during one training session. Although there are many ways to arrange exercises, decisions are invariably based on how one exercise affects the quality of effort or the technique of another exercise. Usually exercises are arranged so that an athlete's maximal force capabilities are available (from a sufficient rest or recovery period) to complete a set with proper exercise technique. Fleck and Kraemer have a great detailed book about how to arrange exercises (Fleck & Kraemer, 2003).

2-1-5- Inter-set Recovery

The time dedicated to recovery between sets and exercises is called the rest period or inter-set rest. The length of the rest period between sets and exercises is highly dependent on the goal of training, the relative load lifted, and the athlete's training status (if the athlete is not in good physical condition, rest periods initially may need to be longer than typically assigned.

The amount of rest between relates heavily on intensity or load, the heavier the loads lifted, the longer the rest periods between the sets. Despite the relationship between training goals and the length of rest periods, not all exercises in a resistance training program should be assigned the same rest periods. It is important that the strength and conditioning professional allocate rest periods based on the relative load lifted and the amount of muscle mass involved in each exercise. An example of this specificity is for an assistance exercise as part of a muscular strength training program. Whereas a core exercise such as the bench press may involve a 4RM load and a 4-minute rest period, an assistance exercise such as the lateral shoulder raise may be performed with a 12RM load and therefore require only a 1-minute rest period (even though 1-minute rest periods generally apply to a hypertrophy training program).

Training goal	Rest periods
Strength	2-5 minutes
Power	2-5 minutes
Hypertrophy	30 seconds - 1.5 minutes
Muscular endurance	≤ 30 seconds

Table N°01: Rest Period Length Assignments Based on the Training Goal (Baechle & Earle, Essentials of Strength Training and Conditioning, 2008).

How long should the inter-set recovery be for developing maximum strength? Prolonging the inter-set recovery attenuates the exercise-induced rise of serum creatine kinase and of the catabolic hormone cortisol (Kraemer, et al., 1993) and will also ensure that the neuromuscular system has enough time to recover and make another maximal effort. Indeed, Robinson et al. showed that for the lower body, a 3-minute rest interval resulted in greater gains in maximum strength than a half-minute rest interval (Robinson, et al., 1995). However, after a successful 1RM attempt in the bench press, a rest interval of 1 minute has been shown to be as adequate as a 10 minute rest interval in ensuring a second successful attempt (Weir, Wagner, & Housh, 1994). Hence, the optimal rest interval should be longer (3–5 minutes) if the athlete is exercising bigger muscle groups , if using sets with higher repetitions or if he is proceeding beyond his second set. Unfortunately, precise rest intervals for different situations cannot be recommended because of a paucity of research in that area.

Although the longer inter-set recovery used by powerlifters and weightlifters will lead to greater maximum strength gains, a shorter inter-set recovery coupled with a moderate training intensity and high training volume (as of that practiced by bodybuilders) may stimulate a greater testosterone response and consequently greater hypertrophy (Kraemer, et al., 1990).

Larson and Potteiger compared 3 different types of rest intervals: a fixed 3-minute rest interval, an interval equivalent to the time it takes the heart rate to drop to 60% of age-predicted maximum, and an interval equivalent to 3 times the exercise duration. All 3 were found to be equally effective methods of estimating the time needed for adequate recovery (Gerald & Jeffery, 1997).

2-2- Training volume:

The training volume is prescribed in terms of the number of repetitions per set, number of sets per session, and the number of sessions per week (frequency). For maximal sets, the load dictates the number of repetitions per set.

The training volume is the total work performed within a specified time. It can be determined precisely by calculating the work done in joules, but total repetitions and volume load (or total load) are simple estimations for training volume that are most commonly used. In resistance training, the most common unit used to measure load is Kg.

As with intensity, training volume is an important stimulus for strength gains. It has been suggested that to develop maximum strength, training volume is perhaps more important than intensity during the initial phase of strength training (Kramer, et al., 1997).

To avoid overtraining and the detrimental rise in serum cortisol, excessively high training volumes should be avoided during periods when high intensities are used. Fry et al. induced overtraining (decrement in 1RM performance) using 10 single-repetition sets daily (70 repetitions per week) at 100% of 1RM squats, whereas a lower-volume protocol using 8 single-repetition sets (40 repetitions per week) at almost the same intensity (95% of 1RM) 5 days a week resulted in 1RM strength increments instead (Fry, et al., 1994).

2-3- Training frequency:

Resistance training frequency is conditional on other training variables and individual's ability to physically adapt from the mechanical stress placed upon the body. Kraemer and Ratamess defined resistance training frequency as several sessions performed during a specific time frame. Considerations towards intersession recovery are needed, as individuals exposed to excessive and frequent resistance stimuli to the same muscle or groups of muscles could lead to over-training and a decrease in strength. Equally, subjects

that have unnecessary intersession recovery may have a detrimental effect on muscular strength due to detraining.

Training frequency rate can vary between individuals depending on many variables such as age, sex and muscle groups. Several studies have demonstrated that a lower frequency of training may be as effective as higher frequency training (Di Brezzo, Fort, & Hoyt III, 2002; DiFrancisco-Donoghue, Werner, & Douris, 2007; Graves, et al., 1988; Kamadulis, Skruvydas, Brazaitis, Imbrasiene, & Masiulis, 2010). While other research indicates that two or three training sessions per muscle per week may produce up to twice the increase in cross sectional area of the quadriceps and elbow flexors, compared to one training session per week per muscle group (Vikne, Refsnes, & Medbø, 1995) (Wirth, Atzor, & Schmidtbleicher, 2002). While these studies contradicted each other's, recent finding show that training frequency does not play a big role such as volume. A2016 study found similar strength and muscle mass gains in people who train once a week versus who train three times a week (Thomas & Bruns, 2016). But it is highly suggested to use high training frequency for beginners (2-3 times a week) (Ralston, Kilgore, Frank, Buchan, & Baker, Weekly Training Frequency Effects on Strength Gain: A Meta-Analysis, 2018).

2-3-1- Maintenance Frequency:

Strength training may need to be curtailed for various reasons such as injury, progression into a phase of more sport-specific training, going into a tapering or transition phase, in-season time constraints, or reducing the risk of overtraining during the in-season. With detraining, strength athletes will exhibit a significant reduction in strength because initial strength levels are high above the baseline. Endurance athletes such as swimmers, on the other hand, will experience little (if any) drop in maximum strength (Neufer, COstill, Fielding, Flynn, & Kirwan, 1987). In basketball players who had undergone a preseason resistance training program but not an in-season program, it was shown that there was a significant drop in 1RM squat performance 10 weeks into the season (compared to the preseason performance) (Hoffman, Fry, Howard, Maresh, & Kraemer, 1991). As much as 68% of the initial isometric strength gains could be lost after 12 weeks of detraining (Graves, et al., 1988), and such losses are accompanied by decreases in maximum IEMG and fiber sizes, as well as a fiber type transition from type IIA to type IIB.

2-3-2- Split workout:

Workout split is a method used by trainees and athletes that helps them construct a well-organized and defined workout plan. The easiest way to split up your training is to work within the confines of the week. Although the body does not specifically follow a seven-day cycle, for practical purposes, a seven-day strength training cycle makes sense with most people's schedules. The following splits for developing strength are one of the easiest ones to apply and they all follow a seven-day cycle and will fit anyone's schedule and level of strengthtraining experience.

a- Whole-Body Strength Training:

Whole-body strength training refers to single workouts that stress most major muscle groups of the body. This training split allows for most major muscle groups to be trained most times of the week. Many experts believe that frequency of training is important for gaining strength. In fact, many strength coaches have their athletes follow a whole-body training system. Not only do they think the frequency of training is important, but most also believe that because the body works as a whole unit, it should be trained accordingly. Therefore, a whole-body strength training split can be an effective means of increasing overall strength (Stoppani, Encyclopedia of Muscle & Strength, 2014).

b- Push–Pull Training Split:

This split divides the workouts into pushing exercises and pulling exercises. Pushing exercises include any exercise in which the positive (concentric) portion of the exercise involves pushing or pressing the weight away from the body (such as in the bench press and shoulder press) or pushing the body away from the floor or platform (such as in the squat).

Pull exercises include any exercise in which the positive (concentric) action involves pulling the weight toward the body (such as in the biceps curl, barbell row, or leg curl) or pulling the body toward a fixed object (such as in the pull-up).

The reason that some weightlifters split their workouts into push-and-pull workouts is that those exercises involve similar muscle groups working together to perform the exercise. For example, the pectoralis, deltoid, and triceps muscles are all used to varying

degrees during the bench press and the shoulder press. Push-and-pull training allows for each workout to be done twice a week for a total of four workouts per week. On push day, it is wise to alternate between the bench press and the squat as the starting exercise (Stoppani, Encyclopedia of Muscle & Strength, 2014).

c- Upper- and Lower-Body Powerlifting Split:

This split divides workouts into an upper-body workout day and a lower-body workout day. The upper-body exercises involve all exercises for major muscle groups of the upper body. The lower-body exercises involve all exercises for the major muscle groups of the lower body.

With an upper/lower split, you train the muscles in your lower body and upper body on separate days. An upper body workout will normally hit your chest, back, shoulders, biceps and triceps, while the lower body workout works your quadriceps, hamstrings, glutes and calves.

Because exercises like squats and deadlifts fall on lower body day, these workouts will also the lower back. Thus the abs workout can be put with any training day.

II. Hypertrophy:

1- Definition of muscle hypertrophy:

Muscle hypertrophy is a term used to define muscle growth or the size increase of the skeletal muscles due to an increase in the length and thickness of each muscle cell without any increase in the number of cells. It results from practicing physical exercises such as weight lifting. The term is often associated with weight training.

Many people think that the larger a person is, the stronger that person is. This is not always the case. For example, a weightlifter may be capable of lifting heavier loads than a larger, bulkier bodybuilder can lift. For this reason, athletes should seek an increase of lean body mass that is functional for their sport, as some hypertrophy, especially of the fast-twitch muscle fibers, contributes to an increase in force expression.

As the preceding distinctions imply, bodybuilding hypertrophy and sport-specific hypertrophy differ in important ways. In bodybuilding hypertrophy, the bodybuilder generally uses loads of 60 percent to 80 percent of 1-repetition maximum (1RM) for sets of 8 to 15 reps taken to failure. Some bodybuilders, however, attribute their success to using fewer reps and high training loads taken beyond failure with forced and negative reps, while others believe in performing as many reps as possible (usually up to 20). Given that all these types of bodybuilders are massively built and share similar records and numbers of wins, we may infer that in professional bodybuilding, it is not only training that makes a difference.

In any case, athletes and coaches of other sports must keep in mind that the purpose of bodybuilding is not optimal performance but optimal symmetry and maximal muscle mass. Aesthetical symmetry, however, is irrelevant to many sports, in which function is the main priority. Although bodybuilders do increase muscle mass, the functionality of that mass is questionable, whereas functionality—that is, improved performance—is the goal of training in other sport. In other words, training for muscle hypertrophy does not refer developing muscle strength and the size of the muscle does not refer to its maximal strength level.

2-How a muscle grow:

The human body contains over 600 muscles, they make up between third to half our body weight. To do any type of voluntary movement, the brain sends a signal to motor neurons to the specific body part that a person wants to move, when the muscles in that area receive the message, they fire, causing the muscles to contract and relax which pull on the bones and generate the needed movement. The bigger the challenge is, the bigger brain's signal grows (Siegel, 2015).

For muscles to get bigger, they go thought a process of damage and repair at the micro level. Small tears, sometimes called microtrauma, this occur in the muscle fibers when they are exposed to stress under load causing microscopic tears. Injured cells release a molecule called Cytokines that activate the immune system to repair the injuries during recovery and that is when hypertrophy happens; the greater the damage to the muscle tissue, the more the body will need to repair it.

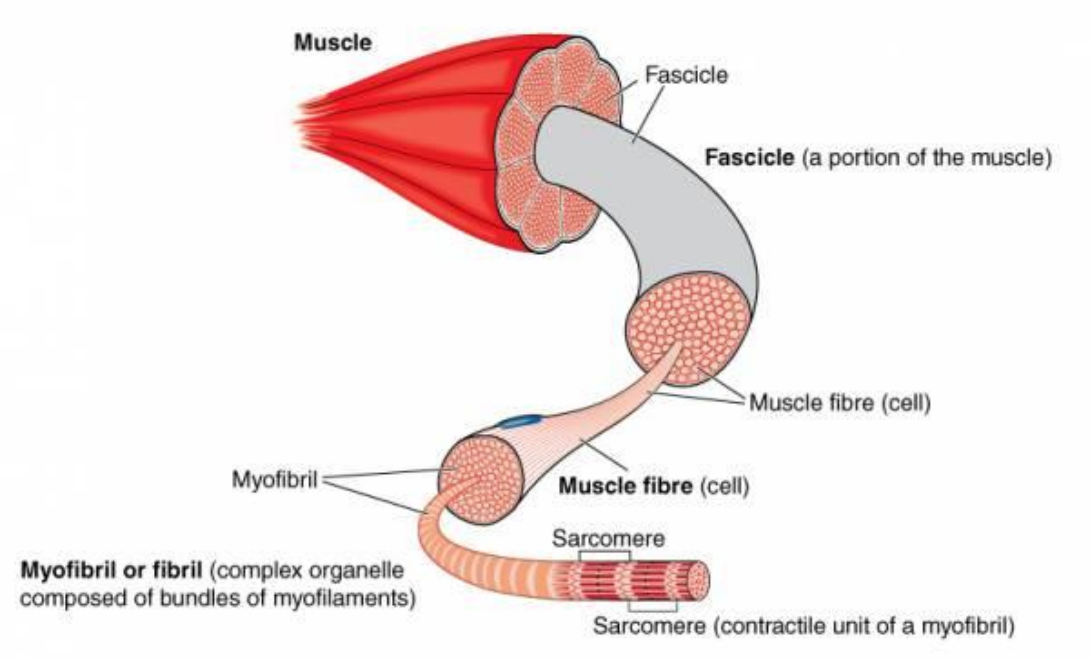

Figure N°02: anatomical structure of a muscle.

Hypertrophy –or muscle tissue damage- occurs during eccentric contraction, this is why trainers advise to go slower during the eccentric movement in order to cause more damage thus better hypertrophy.

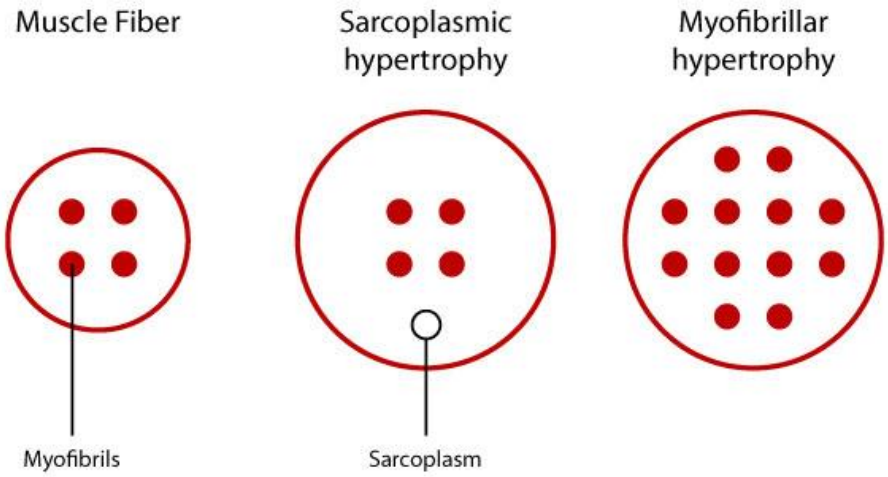

Figure N° 03: types of muscle hypertrophy

Thought hypertrophy results from an increase in the contractile units called myofibrils and from increased fluid in the cell called the sarcoplasm. It is different from hyperplasia which results from the creating of new muscle cells (Baechle & Earle, Essentials of Strength Training and Conditioning, 2008).

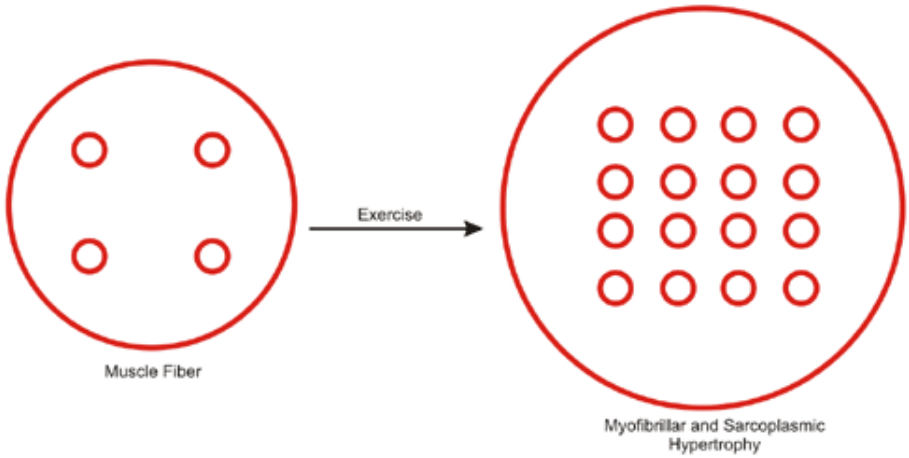

Figure N°04: another type of muscle hypertrophy that combines both myofibilar and sarcoplasmic hypertrophy in result of exercising.

In the 1920's, German biochemist Otto Meyerhof helped figure out many of the steps of Glycolysis. During his experiments, he concluded that lactic acid (or lactate –which is lactic acid minus a proton-) was the cause of muscle soreness. Recent studies disproved this theory (Schwane, Watrous, Johnson, & Armstrong, 1983; Robert, Farzenah, & Daryl, 2004). In fact, other theories suggest DOMS (delayed onset muscle soreness) happens due to microscopic tears in the muscle, which is not proven true yet to this date.

3- Factors that affect muscle hypertrophy:

Individual differences in genetics account for a substantial portion of the variance in existing muscle mass. A classical twin study design (similar to those of behavioral genetics) estimates that about 52% of the variance in lean body mass is estimated to be heritable and that about 45% of the variance in muscle fiber proportion is genetic as well.

During puberty in males, hypertrophy occurs at an increased rate. Natural hypertrophy normally stops at full growth in the late teens. As testosterone is one of the body's major growth hormones, on average, males find hypertrophy much easier (on an absolute scale) to achieve than females and on average, have about 60% more muscle mass than women. Taking additional testosterone, as in anabolic steroids, will increase results. It is also considered a performance-enhancing drug, the use of which can cause competitors to be suspended or banned from competitions. Testosterone is also a medically regulated substance in most countries, making it illegal to possess without a medical prescription. Anabolic steroid use can cause testicular atrophy, cardiac arrest, and gynecomastia. A positive energy balance, when more calories are consumed rather than burned, is required for anabolism and therefore muscle hypertrophy. An increased requirement for protein, especially branch chained amino acids, is required for elevated protein synthesis that is seen in athletes training for muscle hypertrophy.

Training variables, in the context of strength training, such as frequency, intensity, and total volume also directly affect the increase of muscle hypertrophy. A gradual increase in all of these training variables will yield the muscular hypertrophy.

4- Hypertrophy and Training variables:

Consistent with the principle of specificity, proper manipulation of training variables is essential for maximizing exercise-induced muscle hypertrophy. The following is a review as to how each training variable impacts the hypertrophic response with respect to the physiological variables.

These variables include:

- Volume
- Intensity
- Rest interval
- Exercise selection
- Movement speed
- Muscular failure
- Frequency.

4-1- Volume:

Volume refers to the amount of exercise performed over a given time. But in weightlifting, experts define volume as the total number of sets and reps performed in a single training session (sets x reps = volume). Others, on the other hand, like to factor in the amount of weight lifted (sets x reps x weight = total volume).

We can use this equation to track progress throughout week. To compare volume from each week and see how much progress the athlete did.

Studies showed that training volume has a dose-response relationship with hypertrophy. More training volume equals more. So, if the primary focus is on building muscle, then training program should be structured to gradually perform more volume .Over the long haul, athletes should plan on doing a lot more training than they are currently doing to keep disrupting homeostasis, thus causing adaptation.

A meta-analysis done published in 2017 (Schoenfeld, Krieger, & Ogborn, 2017) studying dose response relationship between weekly resistance training volume and increases in muscle mass comprised 34 treatment groups from 15 studies. The outcomes for weekly sets as a continuous variable showed a significant effect of volume on changes

in muscles size. The findings indicate a graded dose-response relationship whereby increases in resistance training volume produce greater gains in muscle hypertrophy.

Another meta-analysisexamining the effect of weekly set volume on strength presenting additional evidence regarding a graded dose-response relationship between weekly sets performed and strength gain (Grant, Kilgore, Frank, & Julien, 2017) . Medium weekly sets and high weekly sets showed more effectiveness than lower weekly sets, with the lower weekly sets producing the smallest pre- to post-training strength difference for novice and intermediate male trainees, suggesting that using medium or high weekly sets is more appropriate to produce more gains.

A 2018 meta-analysis studying weekly training frequency effects on strength gain of a mixed population group (Ralston, Kilgore, Frank, Buchan, & Baker, Weekly Training Frequency Effects on Strength Gain: A Meta-Analysis, 2018). The study found no significant effect of resistance training on muscular strength gain and suggested more investigations are required to explore the effects of varying weekly training frequencies adequately.

A 2018 pilot study done on the effects of a 12 week modified German volume training program on muscle strength and hypertrophy (Hackett, et al., 2018). 12 male subjects were assigned randomly to either a 5 set or 10 set group and performed 5 or 10 sets of 10 repetitions at 60-80% one-repetition maximum (1RM) and measured muscle strength and body composition at baseline, 6 weeks and 12 weeks of training .

The study found no significant change lean mass, with a decrease in lean leg mass in the 10-set group between 6 and 12 weeks.

While training for hypertrophy has both an intensity and volume component, it appears that volume is the more important variable. Research shows that you can gain muscle across a wide spectrum of intensities. As such, lifting super heavy is not required to build muscle. In fact, it might be counter-productive because it limits total training volume. A clear dose-response relationship between volume and hypertrophy has been established. In fact, assuming that an intensity threshold of >60% of 1 rep max is met, it appears that volume is the key determinant of success when it comes to gaining muscle mass.

Researchers believe that higher volumes of training may be more effective than low volume training because of the longer duration of tensile force placed upon the muscle. A greater time under tension increases the potential for micro trauma and the ability to fatigue the full spectrum of muscle fibers. In other words, the muscles have to do more work, which creates more disruption. Thus, adaptation is greater.

Now that we know that more is better, that does not mean athletes (specially beginners) should go all-out, we must respect our bodies' limits, because if we ignore that we will fall in overtraining which can do more harm than good. Progressive overload must take place in here.

4-2- Intensity:

According to another study published in the Journal of Strength and Conditioning Research, you would have to perform 3x the total volume (Robbins, McEwen, & Marshall, 2011), when using a lighter weight, to get the same exact results you would from a moderate load. This is not bashing the idea of building muscles with lighter weights, but it is not as effective as training with heavier loads.

Another study showed similar findings when they compared a low, moderate, and a high rep group. The difference here was, the low and moderate rep groups produced significantly more hypertrophy than the high rep group. This is another study that confirms to achieve better muscle hypertrophy; high intensity plays an important part in it.

The most common method of measuring intensity in weightlifting is the 1RM method (one repetition maximum), which the participant have to lift the maximum load possible in just one repetition. From then, we can calculate the percentage and what load to use according to the cited goal.

4-3- frequency:

Recent review papers showed us that reducing training volume in favor of increasing frequency could have positive effects on muscle hypertrophy (Dankel, et al., 2016; Schoenfeld B. J., Contreras, Vigotsky, & Peterson, 2016). Other studies have shown that training once or twice or three times a week have similar improvements in muscular strength and hypertrophy (McLester, Bishop, & Guilliams, 2000; Brigatto, et al., 2018;

Schoenfeld, Peterson, Ogborn, Contreras, & Sonmez, 2015). Thus, these last studies suggest that training frequency is not as important as other training variables especially for well-trained individuals.

A recent meta-analysis by Brad Shoenfeld et al (2016) concluded that frequencies of training twice per week promoted more muscle growth than once per week, on a volume-equated basis; however, they also added, "whether training a muscle group three times per week is superior to a twice-per-week protocol remains to be determined." Therefore, the importance of higher training frequency for new untrained subject is still unknown.

Another meta-analysis suggested that there is a dose-response relationship between training frequency and muscular strength gains, but if the training volume stays the same, they found no significant effects (Grgic, et al., 2018).

It has been shown that, when training a muscle-group more frequently (to a degree), we increase our ability to recover and adapt.

Muscle Protein Synthesis: the driving force behind adaptive responses to exercise and represents a widely adopted proxy for gauging chronic efficacy of acute interventions, (i.e. exercise/nutrition).

Studies suggest that MPS (Muscle Protein Synthesis) is more than doubled at about 24 hours following a workout. By the 36 hour mark, however, it has dropped back to baseline. It's not hard to see that, despite volume being equal, the person spending more time in this anabolic state will produce greater muscle growth.

Chapter Two: Factors that Affect Strength and Hypertrophy.

I. Nutrition and recovery:

Nutrition is most overlooked aspect in the training field, if the athlete follows a perfect training plan it will not be complete without applying a strict nutrition plan that offers the body all it needs from proteins, carbohydrates, calories, vitamins and minerals that insures a good recovery and helps reach the peak performance. In fact, a bad nutrition plan can affect the athletes performance negatively which may lead to changing the training program, which was not the problem in the first place, for that athletes and coaches need to pay good attention to the nutrition plan in order to achieve the wanted results. Therefore, there is no doubt about it: Nutrition is a big part of the results you get from your training program and it is a big part of maintaining health and general well-being.

Nutrition, as a means of positively affecting physical performance, has become a topic of great interest to all those involved in human performance, the scientist as well as the athlete and athletic trainer. For example, recent studies that implemented the consumption of fluid, carbohydrate, sodium, and caffeine compared with a self-chosen nutritional strategy helped nonelite runners complete a marathon run faster (Hansen, Emanuelsen, Gertsen, & Sorensen, 2014) and trained cyclists complete a time trial faster (Hottenrott, et al., 2012)

Dietary strategies varies according to the individual athlete's sport, personal goals, and practicalities , "Athlete" includes individuals competing in a range of sport types, such as strength and power, team (eg, football), and endurance . The use of dietary supplements can enhance performance, provided these are used appropriately. This manuscript provides an overview of dietary strategies used by athletes, the efficacy of these strategies, availability of nutrition information to athletes, and risks associated with dietary supplement intake (Beck, Thomson, Swift, & von Hurst, 2015).

1- Dietary tips for maximizing muscle mass and muscle strength:

There is a wide range of different nutrition plans, all of which have different goals, some help individuals lose weight, some to gain weight, some that help develop a specific physical ability. But what interests us here is nutrition plans and tips that help the athletes develop strength and assure them better recovery, so that will be our main focus here. After all, building muscle mass and muscle strength go hand in hand to some degree. So

nutrient requirements and timing are very similar whether you are trying to maximize muscle hypertrophy or muscle strength. And more often than not, you are trying to do both at the same time (Stoppani, Encyclopedia of Muscle & Strength, 2014).

Jim Stoppani (2014) provided some guidelines that help maximize muscle growth and strength naturally, we will mention some tips and highlights about what type of foods we need to consume in order to achieve the cited goals:

1-1- Protein intake: Muscles (like many other organs in our body) are made from protein, thus, to make more muscle we need to boost muscle protein synthesis as well as decrease muscle breakdown. Research in the lab and the gym confirms that the best way to do this is with a diet that gets you a minimum of 1 gram per pound of body weight (a little over 2 grams of protein per kilogram of body weight). And even closer to about 3 grams of protein per kilogram of body weight per day. This is especially true for those following more intense training programs.

Victoria University (Australia) researchers had weight-trained men consume about 3 grams of protein per kilogram of body weight per day or 1.5 gram of protein per kilogram during an 11-week weight training program (Cribb, Williams, Stathis, Carey, & Hayes, 2007). The higher protein intake was achieved by supplementing with whey protein. The men who ingested the higher protein gained significantly greater strength and muscle fiber protein in the quadriceps than the control group did.

Another study by also found similar results (Candow, Chilibeck, Facci, Abeysekara, & Zello, 2006), participant males and females who took more protein dose (close to 3grams per kilogram) showed better strength and muscle gains than the control group who took 1.5 grams per kilogram.

In a 2001 study (Burke, et al., 2001) participants' protein intake was increased to 1.5 grams per pound of body weight per day during 6 weeks of weight training with whey protein, while control participants consumed 0.5 gram of protein per pound. At the end of the six weeks, the participants getting the extra protein gained significantly more strength and muscle mass.

A 2011 study also shown that even in endurance athletes, when they double their protein intake to close to 1.5 grams per pound of body weight per day when training

intensity is increased, they recover better and maintain better performance (Witard, Jackman, Kies, Jeukendrup, & Tipton, 2011).

A review study (Bosse & Dixon, 2012) proves that people who weight-train do need more protein consumption than individuals who doesn't or do little to non exercices.

The bottom line is, a rich-protein nutrition plan have very positive effects on developing strength and muscle mass. For optimal results, these studies suggest 1.5 to 3 grams of protein per kilogram of the body weight.

1-2- Fat intake: there are many misconceptions about fat, Fat is an important macronutrient for anyone interested in building muscle and gaining strength as well as optimizing health (Stoppani, Encyclopedia of Muscle & Strength, 2014). The amount of fat we eat does not impact our weight, cholesterol or a risk of heart diseases nearly as much as what type of fat we consume.

There are two types of fat –generally speaking- saturated and unsaturated, unsaturated fats are the ones that hold a lot of benefits to the human body. Though keep in mind unsaturated fats are divided to two types: CIS and TRANS, TRANS (referred to as partially hydrogenated fat) fats are very dangerous and can cause some of the widespread diseases like cardiovascular problems (Willett, et al., 1993).

You can find CIS fats in foods like avocado, olive and olive oil, nuts and seeds … ect. Foods containing CIS fats can decrease the risk of heart disease by improving blood cholesterol levels and lowering blood pressure. They might also reduce the risk of heart attack, abnormal heart rhythms, strokes and death in people with heart disease (McGuire, 2011). Monounsaturated CIS fats can benefit insulin levels and blood sugar control in type 2 diabetics. High doses of CIS fat-containing supplements, such as fish oil, can increase the risk of bleeding and should be taken under medical supervision.

The dietary recommendations of fat intake for athletes is a bit higher than for non athletes. Adequate consumption of essential fatty acids (Broad & Cox, 2008). It is recommended that athletes consume a moderate amount of fat (approximately 30% of their daily caloric intake). Higher-fat diets appear to maintain circulating testosterone concentrations better than low-fat diets. However, for athletes attempting to decrease

body fat it has been recommended that they consume 0.51g/kg/day of fat (Kreider, et al., 2010).

1-3- Carbohydrates: Athletes need to be able to comprehend and manipulate the amount the carbohydrates consumed depending on their goals and training sessions. That means to gain more mass or to lose more fat athletes should be able to change their carb intake. The body can make all the glucose (blood sugar) it needs from protein and fat. So there is no essential carbohydrate you need from your diet. Unlike with essential fat you need to consume, and with protein, there are essential amino acids you need to consume because the body does not make them (Stoppani, Encyclopedia of Muscle & Strength, 2014).

For maximizing muscle growth and strength gains while minimizing fat gains. Individuals engaged in a general fitness program can typically meet macronutrient needs by consuming a normal diet consisting of 45-55% carbohydrates (3-5g/kg/day), 10-15% proteins (0.81g/kg/day) and 25-35% fats (0.5-1.5g/kg/day). Then we can either increase this amount if we find that the athletes are not gaining mass rapidly enough and are not gaining any body fat. Similarly, we can also gradually lower this amount if we find that they are gaining too much body fat. Everyone's body is different, and our bodies will respond to carbohydrate differently. Therefore, we need to experiment with carbohydrate intake.

1-4- Vitamins and minerals: Intense and long period training can cause a significant lost in critical vitamins and minerals such as B vitamins, vitamin C, chromium, selenium, zinc, magnesium and copper. This is due to a variety of factors such as loss in minerals in sweat and urine and energy production during and post workouts.

Therefore, vitamins and minerals are needs for our overall health, organs and brain function and muscle growth

1-5- Fibers: the indigestible part of plant foods the body can't digest. Fiber helps you feel full, aids in digestion, and helps control your weight. The best sources of fiber are whole grains, beans, nuts, fruit and vegetables.

1-6- Water: essential for temperature control, carries nutrients to cells and removes waste from cells, water makes up 60-70% of the body's weight. All cells need water to

function. Water is lost through perspiration, urine, breath, and digestion. It is important to replace lost fluids to avoid dehydration.

1-7- Eating frequently: In a study by Moore and colleagues (2012), participants performed a leg workout and then ate a total of 80 grams of whey protein over the next 12 hours in three methods. They consumed eight 10-gram doses of whey protein every 1.5 hours, or consumed four 20-gram doses of whey every 3 hours, or consumed two 40-gram doses of whey every 6 hours. The researchers reported that protein net balance, which is essentially muscle protein synthesis minus muscle protein breakdown, was significantly greater when they consumed the four 20-gram doses of whey protein every 3 hours as compared to the other two dosing strategies. Greater protein net balance essentially means more muscle growth. Therefore, this study suggests to maximize muscle growth, you should not go much longer than 3 hours between meals. Any longer than this appears to increase protein breakdown too much so that any major boost in protein synthesis you get is just making up for the breakdown and not maximizing the potential for muscle growth. And each meal should contain between 10 to 20 grams of protein.

1-8- Counting calories: The energy contained in nutrients differs because the energyyielding nutrients are composed of different types of chemical bonds. A carbohydrate or a protein yields 4 kilocalories per gram, whereas a lipid yields 9 kilocalories per gram. A kilocalorie (Calorie) is the amount of heat generated by a particular macronutrient that raises the temperature of 1 kilogram of water 1 degree Celsius. A kilocalorie of energy performs one thousand times more work than a calorie. On the Nutrition Facts panel, the calories within a particular food are expressed as kilocalories, which is commonly denoted as “Calories” with a capital “C” (1 kcal = 1 Calorie = 1,000 calories) (Zimmerman & Snow, 2012).

Counting the number of calories from the food we consume is made fairly easy these days, thanks to laws obliging companies to put nutrition fact on the product’s package and applications made for smartphones that estimate the amount of calories of different vegetables, fruits and plates. All of which, helps athletes follow the amount of food needed per day.

2- Sleep:

Going chronically without needed sleep leads to all sorts of negative effects, including performance losses, technique execution difficulties, and profound elevations of cortisol and decreases in testosterone (Alhola & Polo-Kantola, 2007).

Trainers, doctors and physical therapists all suggest an 8 hours' of good sleep per day, but that limit changes from one another, some can sleep for less than 6 hours and recover just fine. Therefore, to answer to how much sleep an athlete needs is to get what is enough for him.

3- Thermotherapy:

Thermotherapy entails various techniques used to heat the body, such as warm water immersion, saunas, steam baths, warm whirlpools, hydrocollator (hot) packs, paraffin baths, and infrared lamps. Thermotherapy is believed to increase subcutaneous and cutaneous blood flow as a result of an increase in cardiac output and a lower peripheral (An, Lee, & Yi, 2019). This increase in blood flow increases cellular, lymphatic, and capillary permeability, which can increase metabolism, nutrient delivery, and waste removal from the cells . It is unlikely that these effects will reach the deep tissue, because the application appears to be localized at the level of the skin. Heat application also may increase neural transmission, muscle elasticity, joint extensibility, analgesia, and reduce muscle spasm.

Thermotherapy does have some contraindications. The most obvious contraindication is that high temperatures can result in burns. The application of heat also can increase inflammatory responses, swelling, and edema (Cardona-Arias, Vélez, & López-Carvajal, 2015). If hot water immersion is used, ectopic beats, hypotension, heat syncope, excessive tachycardia, and in rare instances death can occur. Coaches and athletes must be careful when using thermotherapy for athletes who have open wounds, skin conditions, peripheral vascular disease, impaired circulation, and acute musculoskeletal injuries.

When using a thermotherapy technique, it is important to be aware that there is specific indications and contraindications for each technique:

3-1- Sauna: A sauna may offer some benefit as a recovery intervention. Scoon and colleagues reported that when a 30 min humid sauna (89.9 ± 2 °C) was used as a recovery tool immediately after training, endurance running performance improved. Run time to exhaustion was increased by 32%, and 5K time-trial performance was increased by 1.9%. The authors suggested that the increase in performance may partially be explained by an increase in blood volume. The use of a sauna (60-140 °C; 5-15% humidity) two times a week has been recommended as a recovery intervention in response to whole-body fatigue .

3-2- Warm or hot water immersion: Water immersion with water temperatures greater than 36 °C raises the core body temperature. This increase in core temperature coupled with the increased hydrostatic pressure associated with water immersion may result in a cascade of physiological responses that assist in recovery.

There is very little scientific data to support the effectiveness of warm-water immersion; however, a 10 to 20 min immersion has been suggested to improve recovery. In therapeutic settings, warm whirlpools are used for 10 to 20 min with temperatures that range from 37 to 40 °C for the leg, 37 to 45 °C for the arm or hand, and 37 to 39 °C for the whole body. However, for delayed-onset muscle soreness, cryotherapy or contrast therapy techniques may be more beneficial than thermotherapy.

Coaches are always looking for a way to improve their athletes' performance, and there are many nutrition plans presented by dietarians, nutrition specialists and doctors. Nonetheless, dietary recommendations should be individualized for each athlete and their sport and provided by an appropriately qualified professional to ensure optimal performance. Dietary supplements should be used with caution and as part of an overall nutrition and performance plan (Beck, Thomson, Swift, & von Hurst, 2015). As for when to eat (pre or post nutrition), a 2017 study showed that taking protein supplements before or after a workout have similar effects on muscle adaptations (Schoenfeld, et al., 2017) .

In addition to the nutrition side. Sleep, massage, cryotherapy and doing low stress fun activities are all factors that help in the recovery process.

II. Age and Sex-Related Differences and their Implications for resistance training:

We know that strength training is important essential to reach maximum performance, but we ought to respect the baseline rules in order to reach the intended goal of strength development. One of these rules is the understanding the relation between strength training, age, and sex and how we imply the correct plan depending on these last two variables mentioned above.

With the growing interest in youth resistance training, it is important for strength and conditioning professionals to understand the fundamental principles of normal growth and development. An understanding of these principles and an appreciation for how they can influence training adaptations and confound interpretation of research data are essential to the development and evaluation of safe and effective resistance training programs. Because the training of young athletes is becoming more intense and complex, anatomical and physiological factors that may be associated with acute and chronic injury also need to be considered (Baechle & Earle, Essentials of Strength Training and Conditioning, 2008).

1- Strength training for preadolescence:

The term preadolescence refers to a period of life before the development of secondary sex characteristics (e.g., pubic hair and reproductive organs). Puberty refers to a period of time in which secondary sex characteristics develop and a child is transformed into a young adult. During puberty, changes also occur in body composition and the performance of physical skills.

1-1- Chronological and biological age:

Because of considerable variation in the rates of growth and development, it is not particularly accurate to define a stage of maturation or development by age in months or years, which is known as the chronological age. Children do not grow at a constant rate, and there are substantial inter-individual differences in physical development at any given chronological age.

Stages of maturation, or pubertal development, can be better assessed by the biological age, which can be measured in terms of skeletal age, somatic (physique) maturity, or sexual maturation (Baechle & Earle, Essentials of Strength Training and Conditioning, 2008).

Research suggests that telomeres and DNA methylation play big parts in the aging process. Telomeres are the nucleotides on the ends of chromosomes. They keep the ends of chromosomes from deteriorating and fusing with a nearby chromosome. Essentially, telomeres dictate how quickly cells age and die.

Scientists are also using DNA methylation to determine biological age. Cells use DNA methylation to control gene expression. In other words, DNA methylation turns genes off. Although the exact purpose of methylation is unknown, it is vital to embryonic development, genomic imprinting, chromosome stability and more.

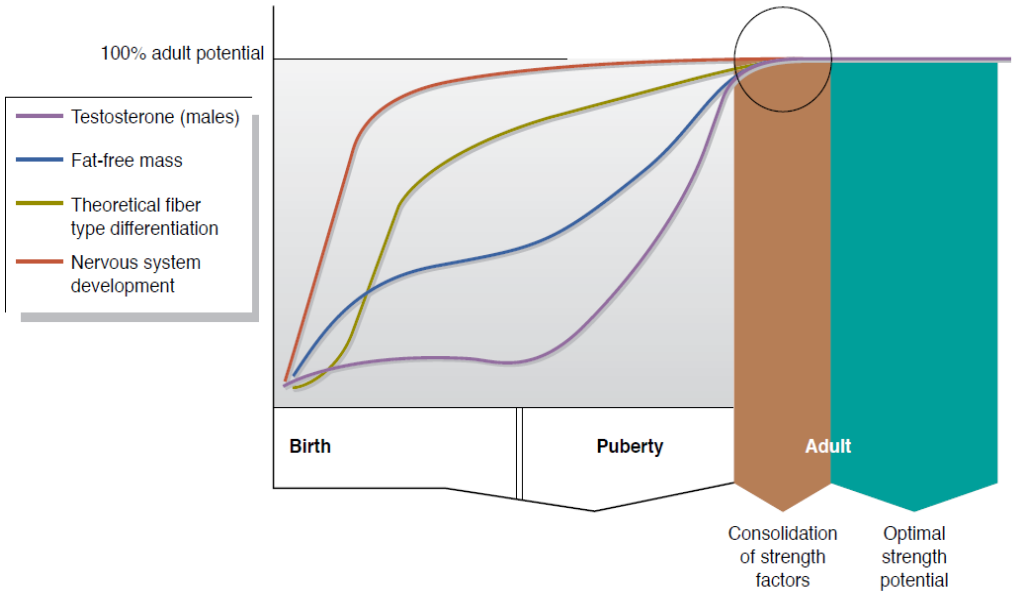

Figure N°05: Theoretical interactive model for the integration of developmental factors related to the potential for muscular strength adaptations and performance. (Kraemer et al. 1989).

1-2- bone and muscle growth:

As children grow. The muscle mass steadily increases throughout the developing years, a newborn body's muscle mass is about 25% of its total weight and 40% in the adulthood. Peak muscle mass occurs between the ages of 16 and 20 years in females and between 18 and 25 years in males unless affected by resistance exercise, diet, or both (Baumgaeter, Curtin, Lindskog, & Keggi, 1995; Gallagher, et al., 1997).

During the period of peak height velocity (pubertal growth spurt), young athletes may be at increased risk for injury (Stone & Kroll, 1986). Peak height velocity usually occurs about age 12 in females and age 14 in males. The relative weakening of the bone during this stage of growth, muscle imbalances between the flexor and extensor groups around a joint, and the relative tightening of the muscletendon units spanning rapidly growing bones are risk factors for overuse injuries in children. Thus, trainers need to change their planning according to this given data.

1-3- preadolescence strength training:

On average, peak strength is usually obtained by age 20 for untrained woman and age 20 – 30 to untrained men. Which means we cannot use high intensity loads in children training duo to it interference with their growth. Trainers and doctors advise to:

- Consider quality of instruction and rate of progression.
- Focus on skill improvement, personal successes, and having fun.
- The use of low intensity during exercises.
- Training-induced gains from a short-duration, low volume training program are not distinguishable from gains attributable to normal growth and maturation.
- Similar to adults, continuous training is needed to maintain the strength advantage of exercise-induced adaptations in children.

2- Strength training for women:

Before puberty, women' body composition appear to be the same as men's according to weight, size and height. As puberty begins and progresses, differences in these measurements become more evident because of the hormonal changes.

At puberty, women tend to have more boy fat mass and less muscle and bone mass than men and lighter in total body weight. Which makes men have more power output compared to women.

Despite sex-related differences, men and women respond to resistance exercise from their pretraining baselines in similar ways. Although the magnitudes of change in selected variables may differ somewhat, the overall trends suggest that the value of resistance exercise for women extends far beyond an increase in muscular strength and includes favorable changes in other important measures of health and fitness (Baechle & Earle, Essentials of Strength Training and Conditioning, 2008). However, studies suggest that women do have specific areas that need to be addressed. Women tend to be weaker in the upper body and trunk musculature . The inclusion of more exercises to strengthen these areas in female athletes may be warranted (Bompa & Haff, Periodization: Theory and Methodology of Training, 2009).

3- Strength training for adults:

For athletes –or fitness trainees- from 20's to the 30's are considered the best age period to push the body to its limits without falling in to injuries and overtraining. These are foundational years where athletes establish habits that will stick with them through adulthood. It's also the beginning to their career, this is why this age period in considered the most important one when it comes to strength training.

While young people tend to be more flexible than older people (Greenhaff, 1995), females tend to be more flexible than males (Bruce, et al., 2000). Differences in flexibility between young men and women may be due in part to structural and anatomical differences and the type and extent of activities performed which should be taken into consideration. Older people undergo a process called fibrosis, in which fibrous connective tissue replaces degenerating muscle fibers (Adamson & Vapnek, 1991). For alders, resistance training is more of a "treatment" than an exercise.

Part Two:
Practical section.

Chapter One: Research Methodology.

1- Experimental design:

A widespread opinion among athletes and trainer is that strength training periodization must pass of four phases: anatomical adaptation, hypertrophy, maximal strength and specialization. Where maximal strength gains are maximized using heavy loads and long rest periods between sets and hypertrophy by using moderate loads and shorter rest intervals.

Recent studies showed that hypertrophy relies more on volume (Schoenfeld, Krieger, & Ogborn, 2017) (Krieger, Single vs. multiple sets of resistance exercise for muscle hypertrophy: a meta-analysis, 2010). We wanted to know if the same outcomes would apply on athletes with minimal weightlifting experience.

This eight weeks period study was preformed to determine the effects of repetition range and intensity on muscle strength and hypertrophy. Tests' outcomes were obtained at the start, 4 weeks and 8 weeks after. Program consisted of two resistance training sessions a week with all sessions supervised by the researcher and an ex-weightlifter athlete.

2- Study's sample:

Fourteen healthy male athletes were selected for this experiment. The selection were based on some of the factors that qualifies them to this study. These factors are: weightlifting experience, the practice of the same sport, history of supplements and drug use and past injuries or chronical diseases. The participants were randomly assigned to two of the study's groups. A group with low repetitions, low volume and high intensity (**LR**) that aimed to train maximal strength (**n**=7; **age**= 22.86 ± 2.19 years; **weight**= 75.57 ± 4.11Kg; **height**=180.3± 5.35cm) and a moderate intensity with high repetitions group and a higher volume (**HR**) that aimed to develop muscle mass (**n**=7; **age**= 21 ±1.41years; **weight**= 75.43 ±4.99Kg; **height**= 182.1 ±7.24cm). Subjects practice team sport (basketball) and preform at least two training sessions per week without counting competition days. All subjects reported a no-use for any kind on drugs or enhancement substances before commencing the study. Participants were also asked to avoid any resistance or strength training that does not respect neither the program designed for them by the researcher nor sessions preformed without a supervisor.

Variables	HR (n=7)	LR (n=7)
Age	21 (1.41)	22.86 (2.19)
Weight (Kg)	75.43 (4.99)	75.57 (4.11)
Height (cm)	182.1 (7.24)	180.3 (5.35)

Table N°02: Baseline descriptive statistics. Data are expressed as the mean (±SD).

3- Controlled variables:

3-1- Age: for our study to be more accurate; participants had to be in the 20-25 years old range.

3-2- Sport practiced: all participants had to participate the same sport with the same number of sessions per week. Practicing different types of sports may influence the final results since different training loads, volumes and intensities are implied to each sport.

3-3- Exercises techniques: technic of execution also needs to be controlled and corrected since the subjects lack some knowledge about the correct technic of some exercises in the aim of avoiding injuries and benefit the most from each repetition.

3-4- Experience: to keep this experiment equal between the two groups. The level of experience had to be equated; participants reported no-to-little past experience in weight lifting. Classification of the experience level was based on NSCA classifying status shown in the table below.

Resistance training status	Current program	Training length and frequency	Training stress	Experience and skills
Beginner	Not training or just began training	<2 months 1-2	Non or low	Non or minimal
Intermediate	Training	2-6 months 2-3	Medium	Basic
advanced	Training	>1 year >3-4	High	high

Table 03: example of resistance training classifying status (NSCA) Baechle & Earle (2008).

3-5- Volume: resistance training volume was intentionally different between the two groups. Volume load (VL) was measured by multiplying the load in the number of sets, multiplied in the number of repetitions (load x sets x reps).

3-6- Effort: we matched effort between participants by using the maximum repetition method. Some caveats need to be highlighted here; one of them is effort which had to be equal for both group. The way we tried to control effort here is by taking all sets performed By subjects from both groups to muscular failure which give us an idea about how many repetition each participant should do per set by giving them a threshold of two to three repetitions to muscle failure.

3-7- Speed of movement: repetition were performed in a controlled manner, thus giving participants an approximately 1 second concentric contraction and 2 seconds eccentric contraction.

4- Preparatory phase of training:

Participants lacked the basic acknowledgement and the experience of weight training. We designed a 1 week resistance training protocol consisted of 3 sessions, the first session we introduced the participants to weight lifting and nutrition tips about what do to before, during and after a workout session. The last two sessions aimed to teach the participants some of the basic technics needed for the designed study and getting them familiarized with all the exercises. We also applied the same exercises preformed in the study with the same order with moderate intensity and volume (3 sets and 10 repetitions for each exercise).

5- Resistance training:

Since we based our study on athletes who play in a championship tournament, we could not imply a training program that involved three training sessions per week, thus, we were limited to only two. We based our program on a split routine that involved performing different exercises targeting specific muscle groups during the two training sessions per week.

We kept flat chest press and squat exercises in both sessions but with a difference in intensity and volume for both, the other exercises were identical for both groups.

The first session consisted of a flat bench press, squat, shoulder press, seated row, biceps curl and core workout, while the second session on the workout plan contained a flat bench press, squat, pull ups, lat-pulldown, triceps press and core workout.

The first group with low reps (LR) preformed the flat bench press and the squat at 90-95% load of a 1RM and 3 sets of 3 repetitions with a 2-5min rest between sets.

The high reps (HR) preformed both exercises at a 60-70% load of 1RM and 5 sets of 10 repetitions with 60-90 sec rest between sets. The reason for the short recovery time is studies found that short rest time between sets induce greater metabolic stress and cause more stress on the muscle fibers causing more micro tears thus better muscle building and better hypertrophy.

1st session			**2nd session**		
exercises	**Load (1RM)**	**Sets X Reps**	**exercises**	**Load (1RM)**	**Sets X Reps**
Flat bench press	60-70% Or 90-95%	5x10-12 Or 3x 3-5	Flat bench press	60-70% Or 90-95%	5x 10-12 Or 3 x 3-5
squat	60-70% Or 90-95%	5x10-12 Or 3x 3-5	squat	60-70% or 90-95%	5x10-12 Or 3x 3-5
Leg press	70%	3 x 6 - 8	Inclined bench press	70%	3 x 6 - 8
Shoulder press	70%	5 X 6 - 8	Pull ups	-	5 X 5 reps
Seated row	70%	3 X 8 - 12	Lat-pulldown	70%	3 X 8 - 12
biceps curl	70%	3 X 8 - 12	triceps	70%	3 X 8 - 12
Core workout	Close to failure	3 sets for each section (abs – lower back – oblique)	Core workout	Close to failure	3 sets for each section (abs – lower back – oblique)

Table N°04: Details of the resistance training intervention of HR and LR

6- Muscle thickness:

The reliability and validity of ultrasound in determining muscle thickness (MT) is reported to be very high when compared with the magnetic resonance (Reeves, Maganaris, & Narici, 2004). However, studies suggest that using a DEXA (dual energy x ray absorptiometry) is more accurate than an ultrasound scanner because it measures the whole muscle body mass and not just the thickness of an individual muscle.

Imaging Ultrasonography measurements were taken 50% between the lateral condyle of the femur and greater trochanter for the quadriceps femoris (Schoenfeld B. J., Contreras, Vigotsky, & Peterson, 2016). The data collected can give us an idea about the development of the muscle mass for each participant. The images were taken at baseline, 4 weeks and post-intervention.

7- Maximal strength test:

Maximal strength in the bench press and squat exercises was measured before, during and after training, participants were scheduled for testing in the weekends were they had no competition assigned for that week. Participants been told to avoid any form of exercise other than daily activities for 48h before test day to avoid any manipulation in our final results.

The one repetition maximum test (1RM) was used to measure the maximal strength for the flat bench press and the squat. The testing was consistent with recognized guidelines established by the National Strength and Conditioning Association (Baechle & Earle, Essentials of Strength Training and Conditioning, 2008). A warm up of a 10 min low paste jogging followed up by a specific warm consisted of 10 bodyweight squats, 10 push-ups, 10 lunges, 10 butt kicks and 10 knee hugs. For each exercise, a warm up set of 5-10 repetitions was performed using 50% of the participant's previous 1RM. After a 1 min rest, participants preform a 70% set of 3 repetitions with 3 min rest after.

Proper technique was enforced on all participants for the results to be valid, after lowering the bar (in both bench press and squat tests) subjects been told to stay in that position until a signal is given by the supervisor.

We gave each participant 3 trials for the1RM test with 3-5min rest after each successful try and documented the best result obtained out of the three trials.

8- Nutrient intake and dietary analysis:

Nutrient plays an important role in muscle strength and hypertrophy, any lack in essential nutrients like protein and carbohydrates can affect muscle growth, thus affecting performance.

Subjects been given a paper that includes some tips about what eat before, during and post training sessions, we advised to take a healthy amount of proteins and carbohydrates two hours before the training session, focus on hydration during the workout and taking a good amount of protein-rich foods in a 12 hours window after workout.

Participants reported what they consumed in the last 24 hours each day before the training session and 24 hours after so we can help guide them to choose the best nutrition plan for building more muscle mass and strength.

9- Statistical analyses:

For statistical analyses, we used SPSS v24 for Windows and an online statistical data analysis from GraphPad.com. Means and standard deviations (SD) were calculated with conventional statistical methods. We used the dependent T test to analyze differences within the groups and used the independent T test to compare baseline characteristics (muscular strength and muscle thickness) and the training variables (volume and intensity) of the two groups (LR and HR) over the 8 weeks.

We also calculated the 95% confidence intervals (CI) and the effect size for each outcome to determine the magnitude of differences found within and between the two groups. For the effect size (ES) we used Cohen's d (**Cohen's d = (M2 - M1)／SD pooled** - where **SD pooled= √((SD12 + SD22)／2)**-)

For classification, an ES of 0.20 or less was considered a trivial effect, 0.21 to 0.59 a small effect, 0.60 to 1.19 a moderate effect, 1.20 to 1.99 a large effect, 2.0 to 3.9 a very large effect, and >4.0 a nearly perfect effect (Hopkins, Marshall, Batterham, & Hanin, 2009).

Chapter Two: Results and Discussion.

Overall, our study was done in good conditions, there were no negative events that may affect the final results as exercise intervention or overtraining, no injuries were noted before, during or after the study period. The bench press total volume for the HR and LR groups were 9038Kg±649 and 34720Kg ±4326 respectively. The total squat volume was 12487.1Kg ±1285.9 for LR and 48882.8Kg ± 4032 for HR.

1- Muscle thickness:

For the quadriceps muscle, both groups noted a significant increase in muscle thickness at 4 weeks (p=0.0009 for LR and p=0.0003 for HR) and 8 weeks (p=00008 for LR and p=0.0003 for HR). However, when comparing between the two groups, there was no significant difference in muscle thickness at any time during the study period (p=0.8776 at 4weeks and p=0.9335 at 8weeks). Both groups had similar results for lower body muscle hypertrophy despite the different training regimens.

Muscle thickness	HR	LR
Baseline	5.48 ±0.52 cm	5.50 ±0.45 cm
4 weeks	5.65 ±0.52 cm	5.61 ±0.45 cm
8 weeks	5.81 ±0.49 cm	5.79 ±0.5 cm

Table N°05: Comparison of absolute means of quadriceps muscle thickness at baseline, 4weeks and 8weeks.

These results show that even with different volumes and loads taken by both groups, both HR and LR saw an increase in muscle mass. While these outcomes prove that it is possible to get similar increased muscle mass when training with higher loads to a volume focused training regimen, our study only measured the lower body portion.

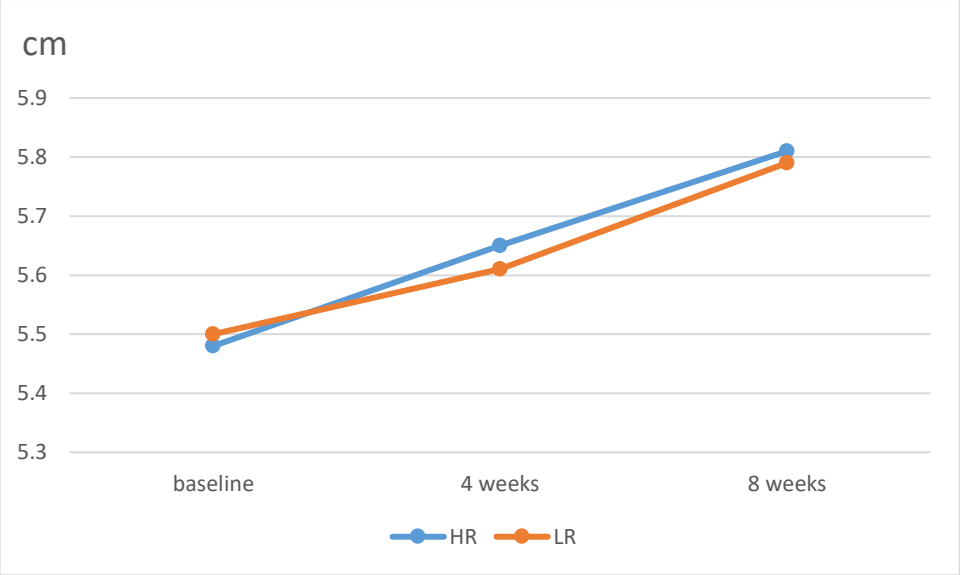

Figure N°06: Quadriceps muscle thickness means comparison between HR and LR.

2- Maximum muscle strength:

Both groups showed an increase for the 1RM flat bench press test but it was more significant for the LR group at 4 weeks ($p<0.0001$ for HR; $p<0.0001$ for LR), although it was not significant ($p=0.1650$ between HR and LR).

At 8 weeks, both groups showed an increase in the 1RM test ($p= 0.0013$ for HR; $p<0.0001$ for LR) but the outcomes became more significant favoring the LR group ($p=0.0201$ between HR and LR).

Squat 1RM test results were similar to the bench press test, both groups showed an increase in maximum strength but results favored the LR group over HR ($p<0.0001$ for HR; $p<0.0001$ for LR at 4weeks, $p=0.0054$ for HR; $p<0.0001$ for LR at 8 weeks). When comparing between the two groups, there was no statistical significant between HR and LR at baseline or 4weeks ($p=0.8391$ at baseline; $p=0.0152$ at 4weeks). LR were statistically significant compared to HR at 8weeks ($p= 0.0165$).

Muscular strength		HR	LR
Flat bench press (Kg)	Baseline	59.86 ±7.71	62.14 ±6.59
	4 weeks	64.14 ±8.35	70 ±6.3
	8 weeks	67.29 ±8.86	78.86 ±7.2
Squat (Kg)	Baseline	84.29 ±7.2	85.14 ±8.2
	4 weeks	90.29 ±7.2	97.43 ±10.6
	8 weeks	95.14 ±8.8	108.4 ±9.88

Table N°06: comparison of absolute means of 1RM test of HR and LR.

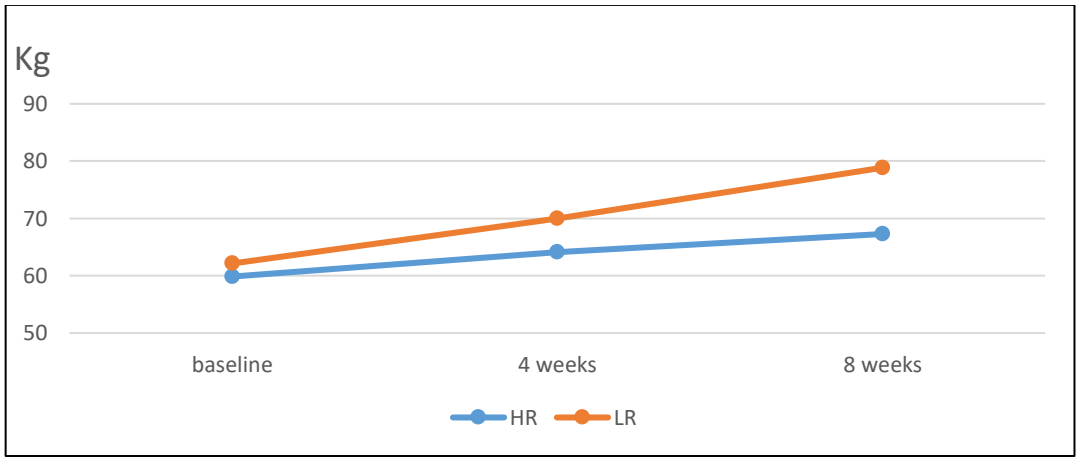

Figure N°07: absolute mean changes of the 1RM bench press test.

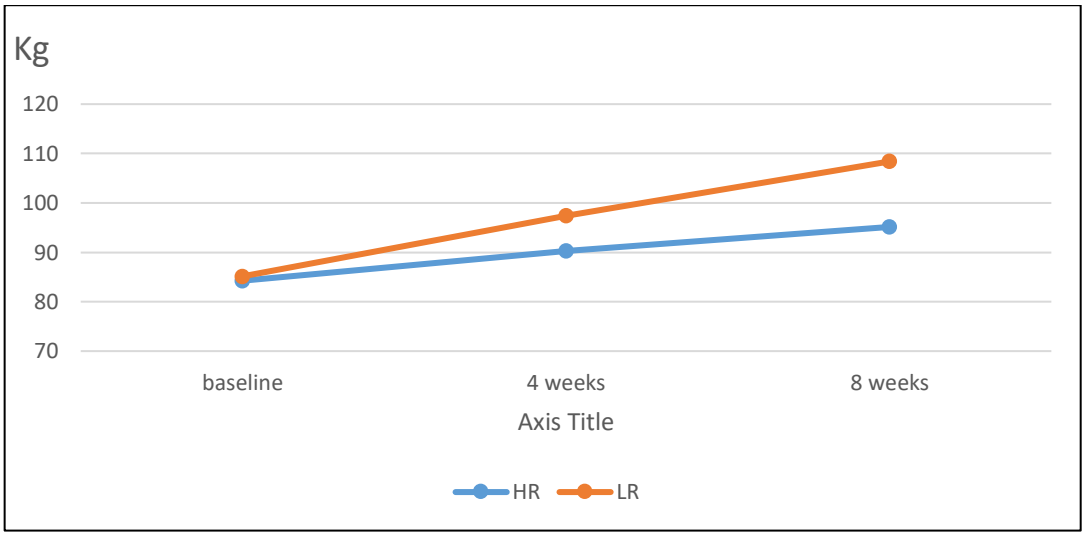

Figure N°08: absolute mean changes in 1RM squat test.

The figures above show a direct comparison of the absolute mean changes for the 1RM flat bench press and the squat test.

While both groups (HR and LR) showed a significant development in the 1RM flat bench press, the results were more noticeable for LR. HR results show a sow rate in the development of the upper body maximal strength rate due to the use of moderate loads (60-70%).

The same can be said about the 1RM squat test. LR showed a very significant increase in maximum strength of the lower body compared to HR. these results proves that the training regime followed by LR was more effective in enhancing maximal strength; moreover, higher loads –or intensities- are recommended to achieve similar results.

We noticed the developing rate of maximal strength in HR group slowed down in at the end of the experiment compared to the data collected in the 4 weeks mark tests considering the 1RM flat bench press and the squat test.

No development dip was noticed in the 1RM flat bench press considering LR group. The 1RM squat test showed a slowdown in the development rate between week 4 and week 8. It is unclear whether this slow rate in maximal power strength gains are related to overtraining, nutrition or recovery thus, we can’t determine the real causes behind it.

The table below shows the ES (effective size) and the 95% CI (confidence interval) within and between the two groups' results.

Tests	period	HR		LR		Between groups	
		Effect size	95% CI	Effect size	95% CI	Effect size	95% CI
1RM bench press	4 weeks	0.53	From -5.31 to -3.26	1.21	From -8.85 to -6.87	0.79	From -14.49 to 2.77
	8 weeks	0.36	From -4.5 to -1.79	1.30	From -10.31 to -7.40	1.43	From -20.99 to -2.16
1RM squat	4 weeks	0.83	From -7.41 to 4.59	1.29	From -15.15 to -9.42	0.78	From -17.67 to 3.39
	8weeks	0.60	From -7.65 to 2.06	1.07	From -13.33 to -8.67	1.42	From -24.44 to -2.99
Muscle thickness	4 weeks	0.32	From -0.23 to -0.11	0.24	From -0.15 to -0.06	0.08	From -0.53 to 0.61
	8weeks	0.31	From -0.21 to -0.10	0.37	From -0.25 to -0.10	0.04	From -0.56 to 0.60

Table N°07: effect sizes for muscle thickness and maximum strength.

As shown, the HR group showed a small effect for the 1RM bench press test during the training period (ES= 0.53 in 4 weeks; ES=0.36 in 8 weeks) when compared to baseline. The LR group showed a more significant development, the LR group witnessed a steady improvement (ES=1.21 and ES= 1.30 respectively) compared to the start. When comparing the two groups the effect size was moderate at 4 weeks (ES=0.79) but at 8 weeks, the effect size became larger (ES=1.43).

For the 1RM squat test, HR group showed a moderate effect size at 4 and 8 weeks (ES= 0.83 and ES= 0.60 respectively) compared to baseline. LR group gave us a large ES at first, but we noticed the effect size became moderate at 8 weeks (ES= 1.29 and ES=1.09 respectively) compared the 1st test. Both groups showed a decrease in the development rate between week 4 and week 8 as shown in the table. Effect size between the two group was considered moderate at 4 weeks and large at 8 weeks (ES=0.78 and ES=1.2 respectively).

These results show that both groups gained a certain amount of skeletal muscular strength but favored the LR group.

As for muscle thickness, both groups showed almost similar results.HR groups resulted in small size effects at 4 and 8 weeks (ES= 0.32 and ES=0.31 respectively) compared to baseline. ESs for LR group were also small over the 8 weeks of training (ES= 0.24 at 4 weeks; ES= 0.37 at 8 weeks) compared to baseline. Effect sizes between HR and LR during the training period were estimated to be trivial (ES= 0.08 at 4 weeks; ES=0.04 at 8 weeks).

3- Discussion:

This study investigated the effects of low repetitions range with high intensity versus high repetition ranges with moderate intensity and volume. Both groups had different training programs, while LR focused on developing maximum strength, HR focused on muscle gain or hypertrophy. Both groups saw an increase in maximal strength, but results show that LR group that had a higher intensity percentage had better results. While both LR showed a consistent development for chest press, HR group shows that performance increase rate was slowing down (ES= 0.53 at4weeks and ES=0.36 at 8 weeks).

Both groups saw a significant increase in maximum strength for the squat 1RM test during the whole experiment. While this increase was considered large at 4 weeks (ES= 0.83 for HR and ES=1.29 for LR), the rate –or consistency- of this development slowed down compared to the first 4 weeks for both groups (ES=0.60 for HR and ES=1.07 for LR).

This could be a result of overtraining since the participants were in a team sport and had a competition day –sometimes two- during the experiment period, or it could be related to other uncontrolled factors like nutrition. Another study is recommended here to investigate these changes in the developing rate.

Contrary to what we hypothesized, muscle thickness results show a significant increase in cross section of the quadriceps muscle throughout all the study stages for both groups. Results were almost identical at 4 weeks (ES=0.32 for HR and ES= 0.24 for LR) and at 8weeks (ES= 0.31 for HR and ES=0.37 for LR). Results show that LR had a consistent developing rate of the quadriceps muscle while HR stagnated at 8 weeks. It is difficult to explain if this slack in muscle mass development was due to overtraining or recovery, further investigation is need here.

A 2017 study (Hackett, et al., 2018) about the effects of a modified German volume training program on muscle strength and hypertrophy also found similar results, the study was done on participants with less than a 1-year experience. Results show a decrease in lower body muscle mass after between 6 and 12 weeks of training. Which may explain our outcomes considering the decrease in muscle mass gains.

More and more findings have shown us in the last years that hypertrophy training relies more on volume (especially for experienced athletes), one of the ways to describe the training volume is a week period that is used by most athletes and trainers. A 2010 study by Nicholas A.brud et al. showed that low load-high volume resistance training stumilate more muscle protein synthesis than a high load-high volume training for young men. Another study (Schoenfeld B. J., et al., 2019) also showed that resistance training volume plays a big role in gaining muscle mass but not strength development in trained men. Despite the recent finding about the relation between training volume and hypertrophy, it is still unclear whether athletes should focus only on volume to gain more muscle mass. A 2015 study found that using low volume-high intensity training program utilizing a long rest interval (3 min) and 3-5 repetitions in each set is more advantageous that a moderate intensity-high volume (10-12 repetitions) program using a short rest interval (1 min) for stimulating upper body strength gains and hypertrophy (Mangine, et al., 2015). This study supports our finding that a higher load and a low volume training program can lead to a significant increase in maximal strength and muscle mass.

4- Study's difficulties:

Some limitations have to be taken into account when interpreting our study's results:

The diet of our participants were not monitored, which may have confounded the results.

Studies showed that the changes in the muscle mass gain of the lower versus upper body are not the same. A 2000 study gave us some evidence that the upper body compared the lower body have an increased hypertrophic capacity (Abe, DeHoyos, Pollock, & Garzarella, 2000).

Our muscle thickness measurement's method only measured thickness of the quadriceps' cross section, which means we only studied muscle mass development of the lower body. It is advised to also measure elbow flexors and forearms muscles' thickness in order to deem the study more accurate.

Even though there were no adverse events reported by the participants. We did not use any methods or monitors to measure fatigue and soreness, which could help make conclusions that are more definitive.

Finally, the number of participants in this study is very low (n=14), results could be different with a larger sample size; furthermore, the type of respond of each participant can change from one another (Marshall, McEwen, & Robbins, 2011).

Conclusion:

This study investigated the effects of repetition range on maximal strength gains and hypertrophy. The final results of this 8 weeks resistance training program suggests that it's possible to gain better muscle mass with higher loads (intensities) and a low number of repetitions (3-5) compared to training with moderate loads, a higher volume and a higher number of repetitions (10-12). These observations question the utility of a high-volume training programs used as a second phase in strength training periodization by coaches and trainers. Emphasizing training intensity over volume may provide an advantage for accelerating muscle growth and strength gains in a short-term training cycle. Further complimentary studies are needed with better monitoring system and control on critical variables like nutrition and recovery to consider our findings valid.

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Annex.

Example of a health questionnaire given to the participants

الاسم واللقب: .....

السن: .....

الطول: .....

الوزن: .....

	الاسئلة	نعم	لا
01	هل يعاني أي فرد في عائلتك من مرض مزمن؟		
02	هل تعاني من أي مرض مزمن؟		
03	هل تشعر بالدوار عند ممارسة الرياضة؟		
04	هل تحس بألم في الصدر عند ممارسة الرياضة؟		
05	هل تعاني من ضيق في التنفس؟		
06	هل توقفت يوما عن ممارسة الرياضة لأسباب صحية؟		
07	هل لديك نسبة كولسترول مرتفعة؟		
08	هل تتعب بسرعة مقارنة مع أصدقائك عن ممارسة التمارين؟		
09	هل لديك مشاكل في القلب؟		
10	هل لديك مشاكل في الجهاز الهضمي؟		
11	هل قمت بإجراء أي عملية جراحية من قبل؟ ما نوع هذه العملية؟		
12	هل تدخن؟		
13	هل استهلكت مواد مخدرة أو مهلوسة من قبل؟		
14	هل تعاني من الإدمان الى أي مادة محضورة؟		
15	هل تعاني من أي مشاكل في الحركة؟		
16	هل لديك مشاكل في التغذية؟		
17	هل تستهلك أي نوع من المكملات الغذائية؟		
18	هل إستهلكت مواد منشطة من قبل؟		

بعض النصائح العامة:

قبل التدريب:

- تناول كمية من المأكولات التي تحتوي على الكربوهيدرات (بسكويت، ازر، فاكهة، حليب، خضر ...).
- تجنب المأكولات المشبعة بالدهون.
- تجنب الأكل لمدة ساعتين قبل التدريب.
- شرب القهوة او الشاي كمنشط طبيعي يساعد في الأداء الجيد.

خلال الحصة التدريبية:

- القيام بتسخين جيد لأعضاء الجسم المراد تدريبها.
- عدم الإسراع في القيام بالتمارين.
- أخذ الراحة اللازمة بين التمارين (60 – 90 ثا).
- شرب الماء.

بعد التدريب:

- من المستحسن تناول أطعمة غنية بالألياف مثل الخضر، البقوليات، خبز الشعير. والبروتينات مثل البيض واللحوم الحمراء والبيضاء، وهذا من ساعة إلى 6 ساعات (12 ساعة كأقصى حد) بعد التدريب.
- أخذ قسط كاف من النوم (8 ساعات).

Name: ……..

Surname: ……

Age: ……..

Height: …….

Group:

Workout plan

1st session			**2nd session**		
exercises	**Load (1RM)**	**Sets X Reps**	**exercises**	**Load (1RM)**	**Sets X Reps**
Flat bench press	60-70% or 90-95%	3x10-15 or 3x 3-5	Flat bench press	70-75% or 90-95%	3 x 10-15 or 3 x 3-5
squat	60-70% or 90-95%	3 or 5 X 3 - 10	squat	70-75% or 90-95%	3 or 5 X 3 – 10
Leg press	70%	3 x 6 - 8	Inclined bench press	70%	3 x 6 - 8
Shoulder press	70%	5 X 6 - 8	Pull ups	-	5 X 5 reps
Seated row	70%	3 X 8 - 12	Lat-pulldown	70%	3 X 8 - 12
biceps curl	70%	3 X 8 - 12	triceps	70%	3 X 8 - 12
Core workout	Close to failure	3 sets for each section (abs – lower back – oblique)	Core workout	Close to failure	3 sets for each section (abs – lower back – oblique)

Groups' statistics

Participants (HR)	age	height	weight
M.B	23	184	77
J.S	21	179	71
H.S	20	183	76
B.A	20	196	82
B.M.A	20	180	76
J.C	23	181	79
A.B	20	172	67
Mean	21 (1.41)	182.1 (7.24)	75.43 (4.99)

Participants (LR)	age	height	weight
K.I	25	177	73
A.A	20	180	76
B.M	20	183	80
A.M	22	171	69
C.R	24	186	80
J.S	24	179	73
H.M	25	186	78
Mean	22.86 (2.19)	180.3 (5.35)	75.57 (4.11)

Flat bench press 1RM test results:

HR	1st	2nd	3rd
M.B	60	65	68
J.S	62	65	70
H.S	52	55	58
B.A	50	54	55
B.M.A	57	62	65
J.C	72	78	80
A.B	66	70	75
mean	59.86± 7.71	64.14± 8.35	67.29± 8.86

LR	1st	2nd	3rd
K.I	60	68	74
A.A	62	70	80
B.M	57	65	74
A.M	70	79	88
C.R	70	77	88
J.S	64	70	79
H.M	52	61	69
mean	62.14± 6.59	70± 6.3	78.86± 7.2

Squat 1RM test results:

HR	1st	2nd	3rd
M.B	88	92	94
J.S	80	87	90
H.S	78	82	88
B.A	82	88	92
B.M.A	76	84	87
J.C	96	102	107
A.B	90	97	108
mean	84.29± 7.2	90.29± 7.2	95.14± 8.8

LR	1st	2nd	3rd
K.I	80	92	102
A.A	87	96	104
B.M	72	80	96
A.M	94	110	122
C.R	94	107	118
J.S	89	105	115
H.M	80	92	102
mean	85.14± 8.2	97.43± 10.6	108.4± 9.8

Biceps curl 1RM test results:

HR	1st	2nd	3rd
M.B	20	22	24
J.S	20	24	28
H.S	18	21	25
B.A	18	20	26
B.M.A	20	22	26
J.C	25	24	32
A.B	22	26	30
mean	20.43 ± 2.44	22.71 ± 2.05	27.29 ± 2.87

LR	1st	2nd	3rd
K.I	20	23	25
A.A	22	24	28
B.M	20	22	22
A.M	18	20	21
C.R	22	25	34
J.S	25	29	37
H.M	18	22	28
mean	20.71 ± 2.49	23.57 ± 2.87	27.86 ± 5.92

Pull ups (max repetitions test):

HR	1st	2nd	3rd
M.B	07	10	12
J.S	05	8	12
H.S	04	08	10
B.A	00	6	8
B.M.A	09	13	14
J.C	06	08	10
A.B	08	09	14
mean	5.57 ± 2.99	8.85 ± 2.19	11.43 ± 2.22

LR	1st	2nd	3rd
K.I	02	05	09
A.A	05	09	13
B.M	01	05	08
A.M	03	08	08
C.R	09	10	12
J.S	08	10	13
H.M	06	08	11
mean	4.85 ± 3.02	7.85 ± 2.11	10.57 ± 2.22

Lat-Pulldown 1RM test results:

HR	1st	2nd	3rd
M.B	65	70	72.5
J.S	50	52.5	57.5
H.S	47.5	52.5	55
B.A	55	60	65
B.M.A	57.5	60	67.5
J.C	55	62.5	70
A.B	60	67.5	70
mean	55.71 ± 5.90	60.71 ± 6.72	65.36 ± 6.68

LR	1st	2nd	3rd
K.I	50	55	62.5
A.A	47.5	57.5	65
B.M	55	60	62.5
A.M	60	60	67.5
C.R	70	75.5	80
J.S	67.5	75.5	82.5
H.M	52.5	65	70
mean	57.5 ± 8.66	64.07 ± 8.37	70 ± 8.16

Triceps pushdown 1RM test results:

HR	1st	2nd	3rd
M.B	22.5	27.5	37.5
J.S	20	22.5	32.5
H.S	20	27.5	32.5
B.A	22.5	27.5	30
B.M.A	25	30	32.5
J.C	22.5	27.5	30
A.B	25	30	32.5
mean	22.5 ± 2.04	27.5 ± 2.5	32.5 ± 32.5

LR	1st	2nd	3rd
K.I	20	25	32.5
A.A	17.5	22.5	27.5
B.M	20	22.5	30
A.M	20	27.5	35
C.R	22.5	30	37.5
J.S	25	30	37.5
H.M	20	27.5	32.5
mean	20.71 ± 2.37	26.43 ± 3.18	33.21 ± 3.74

Shoulders press 1RM test results:

HR	1st	2nd	3rd
M.B	28	35	40
J.S	35	37	43
H.S	25	32	35
B.A	37	42	50
B.M.A	37	40	46
J.C	35	40	42
A.B	40	48.5	52
mean	33.86 ± 5.36	39.21 ± 5.32	44 ± 5.85

LR	1st	2nd	3rd
K.I	40	45	52
A.A	35	37	45
B.M	20	27	32
A.M	37	40	42
C.R	42	47	50
J.S	40	45	50
H.M	32	36	40
mean	35.14 ± 7.49	39.57 ± 6.97	44.43 ± 7.06

Seated row 1RM test results:

HR	1st	2nd	3rd
M.B	77.5	82.5	90
J.S	77.5	80	82.5
H.S	65	70	77.5
B.A	75	80	82.5
B.M.A	77.5	82.5	92.5
J.C	70	80	85
A.B	72.5	82.5	90
mean	73.57 ± 4.75	79.64 ± 4.43	85.71 ± 5.34

LR	1st	2nd	3rd
K.I	70	77.5	82.5
A.A	75	80	87.5
B.M	65	72.5	75
A.M	72.5	77.5	87.5
C.R	72.5	80	95
J.S	75	85	97.5
H.M	70	77.5	80
mean	71.43 ± 3.49	78.57 ± 3.78	86.43 ± 8.01

Quadriceps' muscle thickness results:

HR	1st	2nd	3rd
M.B	5.03	5.20	5.33
J.S	5.85	5.97	6.11
H.S	4.81	5.01	5.19
B.A	5.00	5.19	5.44
B.M.A	5.99	6.23	6.33
J.C	6.05	6.28	6.39
A.B	5.64	5.71	5.94
mean	5.48 ± 0.52	5.65 ± 0.52	5.81 ± 0.49

LR	1st	2nd	3rd
K.I	5.10	5.19	5.35
A.A	5.63	5.71	5.94
B.M	5.11	5.27	5.37
A.M	5.17	5.22	5.40
C.R	6.28	6.35	6.68
J.S	5.92	6.09	6.22
H.M	5.33	5.47	5.61
mean	5.5 ± 0.45	5.61 ± 0.45	5.79 ± 0.5

T. Test table:

	HR	LR	Between HR & LR
Flat bench press	14.06	27.57	2.67
Squat	8.02	23.32	2.78
Muscle thickness	15.02	13.7	0.08