Title: Amino acid consumption and muscle mass

Research Question:

To what extent do the essential amino acids leucine, lysine, valine, phenylalanine and methionine present in whey amino acid consumption increase growth on muscle mass and size and what reasons cause this growth.

Biology Extended Essay

Candidate Number:

Centre Number:

Word Count: 3983

Contents

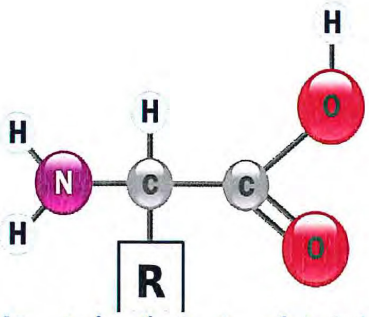


Figure 1, Image to show the structure of a typical amino acid
http://homepages.ius.edu/DSPURLOC/c122/amino.htm

Introduction

This investigation identifies the extent to which leucine, lysine, valine, valine and methionine as essential amino acids present in whey amino acid consumption increase muscle mass and size.

Often referred to as the study of life, biology is one of the three siblings of scientific study and is undoubtedly a key area of research and scientific significance. With many branches stemming from biology, the area of amino acids is one of the areas that are heavily researched due to their ability to carry out both anabolic and other synthesizing reactions and their importance to the functioning of the body. It is for this reason that specifically biology in amino acids is worthy of research. Furthermore, an example of amino acids being a scientific area of study is from the various experiments conducted on their specific role in building muscle mass and size. Now known as Essential Amino Acids, these amino acids are responsible for the synthesis of muscle and muscle proteins and offers evidence into further research and significance in scientific study. From the apparent evidence of amino acids being worthy of research, the research question 'To what extent do the essential amino acids valine, leucine, lysine, methionine and phenylalanine present in whey amino acid consumption increase muscle mass and size and what reasons cause this growth' was founded. With direct focus on essential amino acids and their role on increasing muscle mass and size this investigation can be identified as a further focused, reliable and accurate source of scientific evidence into amino acids and their role in the human body. At the same time, this investigation offers more deeper, insightful knowledge in the area of amino acids as it outlines the specific reasons of how these essential amino acids increase muscle mass and size,

therefore further understanding can be identified and possible future outcomes in influencing the level of which these amino acids increase muscle mass and size.

Investigation

Hypothesis:

The essential amino acids valine, leucine, lysine, phenylalanine and methionine that are present in whey amino acid consumption increase muscle mass and size.

Apparatus

- 1 healthy male subject with a Body Mass Index between 18.50 – 24.99
- Gym (preferably local)
- 1 Whey Amino Acid (with scoop)
- Table for recording measurements
- Protein shake bottle
- Tape Measure

what exactly is in this?

http://www.citygymportsmouth.com/page/ga

http://www.factorysupplements.co.uk/opti

http://www.myprotein.com/protein-accesso

Method of Experiment

This method is used to find out if continuous whey amino acid consumption increases muscle mass and size by consuming whey amino acid for 8 weeks. The measurements of the body are investigated on.

-Body parts to be measured:

*Chest width

*Shoulder width

*Upper arm perimeter (both left and right)

*Forearm circumference (both left and right)

*Thigh circumference (both left and right)

*Waist

Example of a table of measurements:

Body part measured/cm	Average/cm	Trial 1/cm	Trial 2/cm	Trial 3/cm	Trial 4/cm	Trial 5/cm	Standard Deviation	Percentage Uncertainty (%)
Chest width								
Upper arm (right arm)								
Upper arm (left arm)								
Forearm (right arm)								
Forearm (left arm)								
Thigh (Left leg)								
Thigh (right leg)								
Calf (right leg)								
Calf (left leg)								
Waist								
Shoulder width								

Method

Preliminary:

-Purchase 1 whey amino acid container. Must be Gold Standard Whey amino acid.

- Design 9 tables of measurements of the body as seen above. First table is measurements of the body without any whey amino acid consumption. Each table then on is from week 1-8.

Note:

- Allow 2 days for rest and recovery so that the amino acids will be able to increase muscle mass and size.

- Monday, Wednesday and Friday are rest days.

- After all exercises have been completed for that day, mix 2 scoops of the whey amino acid with semi skimmed milk within a protein shaker cup, after mixing it consume the whey amino acid.

Tuesday = Shoulders		
Exercise	**Reps**	**Sets**
Military Press	6	4
Hang Clean & Press	6	4
Dumbbell shoulder press	6	4
Upright barbell rows	8	3
Overhead Squat	10	3

Table 1, to show the required exercises for exercising the shoulders on Tuesday.

Thursday = Arms		
Exercise	**Reps**	**Sets**
Standing Barbell curl	6-8	4
Seated alternating dumbbell curl	3	8-10
Standing 2 arm cable curl	3	10-12
One arm preacher curl	3	10-12
Reverse preacher curl	3	12-15

Table 2, to show the required exercises when exercising the arms on Thursday.

Friday = Legs		
Exercise	**Reps**	**Sets**
Leg extensions	15	2
Power cleans	6	3
Squats	20	1
Romanian deadlifts	10	4
Hamstring curls	12	3
Seated calf raises	12	3

Table 3, to show the required exercises for exercising the legs on Friday.

Sunday= Chest		
Exercise	**Reps**	**Sets**
Incline Barbell press	8	4
Flat bench dumbbell press	8	4
Dumbbell decline press	8	4
Incline Dumbbell Fly	8	4
Cable Crossover	12	4

Table 4, to show the required exercises when exercising the chest on Sunday.

Argument: Part A) Results

Diagram 1, showing the increase in muscle mass and size on the chest from whey amino acid consumption over 8 weeks

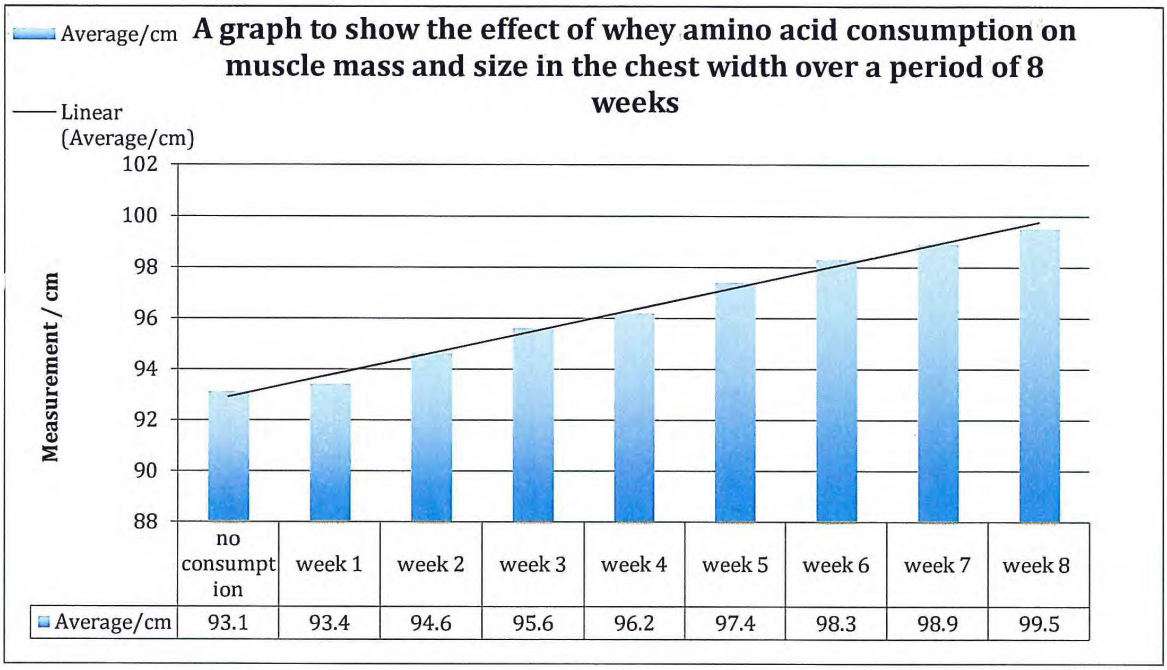
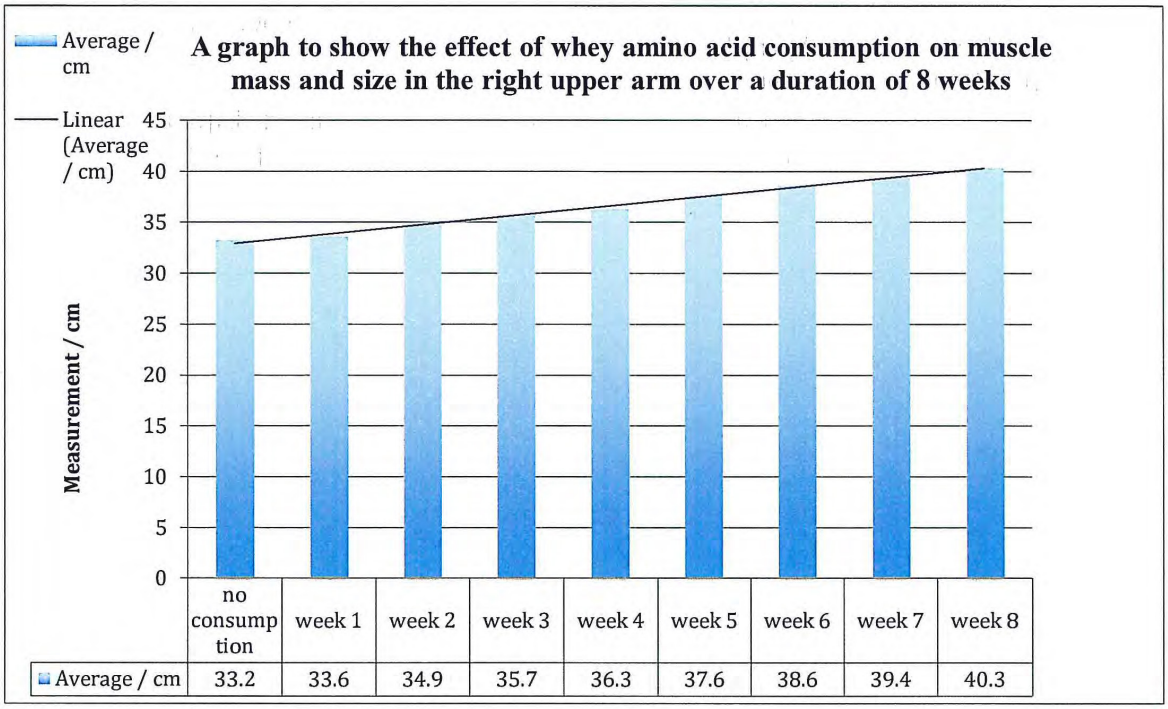


Diagram 1, 'A graph to show the effect of whey amino acid consumption on the chest width over a period of 8 weeks', is supportive evidence towards my hypothesis. Reasons for this are seen in the increasing trend identified on the graph. With no consumption the measurement of chest width was 93.1cm. On the 8th week of consuming whey amino acid consumption results showed an average of 99.5cm indicating there has been an increase of 6.4cm in muscle mass and size in the chest. No anomalous results were found during the measuring of whey amino acid consumption as each week showed an increase in muscle mass and size of the chest width. Overall, diagram 1 is representative of supportive evidence in confirming my hypothesis and that continuous consumption of whey amino acid demonstrates an increasing effect on muscle mass and size to a large extent.

Diagram 2, showing the increase in muscle mass and size in the right upper arm from whey amino acid consumption over 8 weeks



	no consumption	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8
Average / cm	33.2	33.6	34.9	35.7	36.3	37.6	38.6	39.4	40.3

Diagram 2, 'A graph to show the effect of whey amino acid consumption on muscle mass and size in the right upper arm over a period of 8 weeks', is supportive evidence towards my hypothesis. The graph shows an overall increasing trend in consumption of whey amino acid in the increase of muscle mass and size. Evidence of this can be seen in the measurement of the upper right arm with no consumption of whey amino acid resulting in an average of 33.2cm. At week 8 of consuming whey amino acid, the average result was 40.3cm showing an overall increase of 7.1cm in muscle mass and size in the right upper arm from consuming whey amino acid. In terms of anomalous results, all results are reliable and are averaged indicating that any anomalous result identified was discarded previous to calculating an average. Overall, diagram 2 is representative of evidence in the confirmation of my hypothesis and that continuous consumption of whey amino acid demonstrates an increasing effect on muscle mass and size to a large extent.

Diagram 6, showing the increase of muscle mass and size in the right thigh from whey amino acid consumption over 8 weeks.

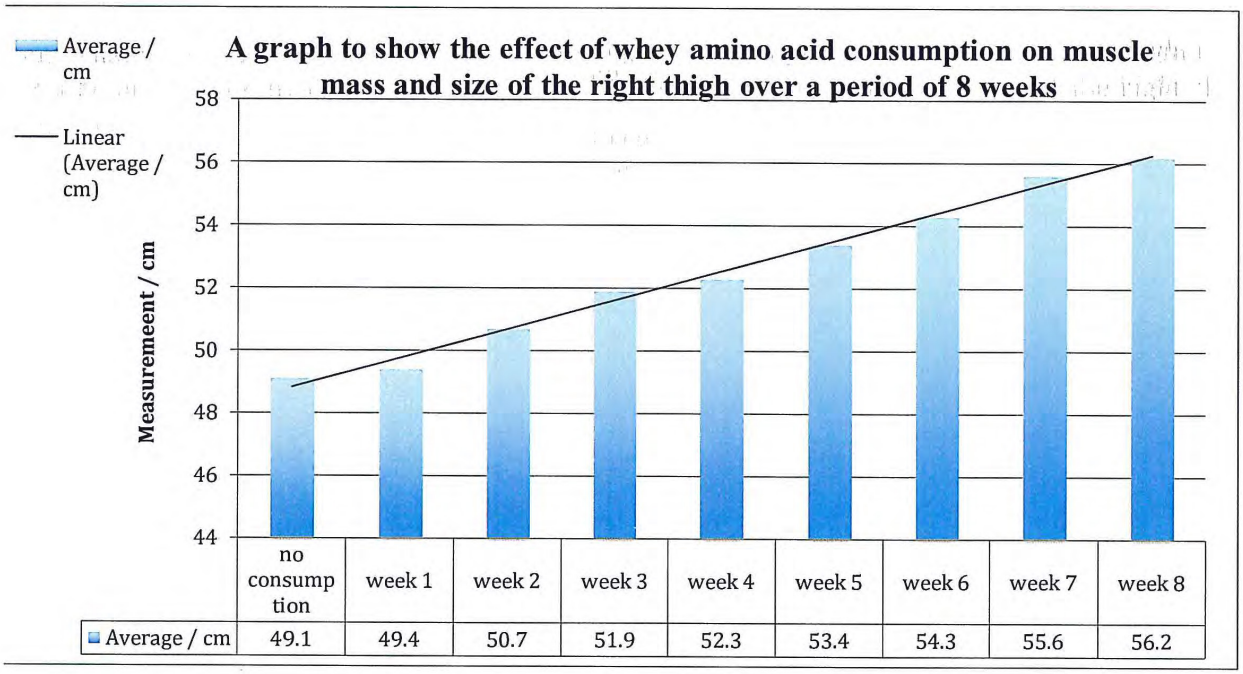


Diagram 6, 'A graph to show the effect of whey amino acid consumption on muscle mass and size in the right thigh', is supportive evidence for my hypothesis. Evidence for this can firstly be seen in the trend in the graph that is an overall increasing trend with some evidence of large increases between some results. Data to support this can be seen in the measurement of the right thigh before any consumption that was identified as 49.1cm. Measurement for the 8th and final week of whey amino consumption showed that the right thigh was now 56.2cm. Overall, this showed a total increase of 7.1cm in muscle mass and size in the right thigh from consuming whey amino acid. In terms of anomalous results, week 1 with the measurement of 49.4cm was in comparison, an outlying result. Reasons for this could be from the equipment used of a tape measure that cannot provide total accuracy of results. Overall, diagram 6 is representative as supportive evidence in the confirmation of my hypothesis and secondly that continuous consumption of whey amino acid demonstrates an increasing effect on muscle mass and size to a large extent.

Diagram 11, showing the increase in muscle mass and size in the shoulder width from whey amino acid consumption over 8 weeks

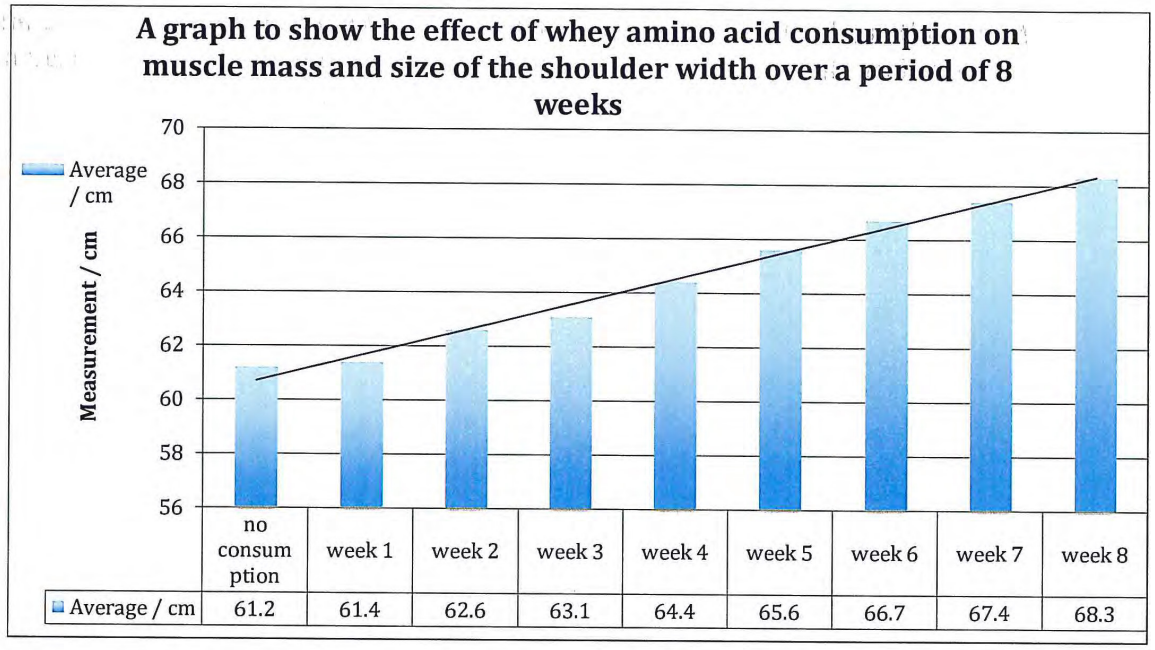


Diagram 11, 'A graph to show the effect of whey amino acid consumption on muscle mass and size of the shoulder width over a period of 8 weeks', provides supportive evidence of my hypothesis. Evidence for this can be firstly seen in the trend in the increasing trend of the graph with some moderate inclines in the results. The data to support this can be seen in the 61.2cm measurement of shoulder with when no consumption of whey amino acid had occurred. In contrast, the measurement for the 8th and final week of consuming whey amino acid was identified as 68.3cm showing a total increase of 7.1cm of muscle mass and size in shoulder width. In terms of anomalous results, week 3 of 63.1cm can be identified as an anomalous result as it does not meet the line of best fit and is therefore classed as an outlier. Reasons for this occurrence may pose to be from the equipment used to measure the shoulder width, as it does not provide total certainty and accuracy of the result. Overall, diagram 11 provides supportive evidence in the confirmation of my hypothesis and secondly that the continuous consumption of whey amino acid demonstrates an increasing effect on muscle mass and size to a large extent.

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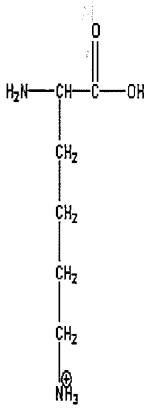
Argument: Part B) Amino Acids



The chemical structure of a lysine molecule.

http://vagabondguru.com/BluePenguinReportDaily/2009/05/amino_acids_proteins_and_bionanotechnology_pt_1.html

Lysine

Discovered by Dreschel in 1889 when he isolated it from casein. It is one of the 20 Amino Acids and is also part of the Essential Amino Acids (EAA's), meaning that the body cannot produce lysine and is therefore found in foods and dietary supplements (AminoAcidsGuide, 2013). It is responsible in helping build muscle proteins, bones and more importantly, lysine is responsible for calcium absorption (AminoAcidsGuide, 2013) and collagen formation. Collagen formation and calcium absorption are the two ways in which this amino acid builds muscle mass and size and is found in whey amino acid.

Calcium Absorption

Calcium absorption primarily provides growth and repair of muscles and bones and also provides development for these skeletal structures; without it, our bones, cartilage and muscles would become weak, brittle and useless. Lysine aids in the increased absorption of calcium and provides enough of it to support both our bones and muscles. Lysine can be found in dietary supplements such as Whey Amino Acid and also in foods such as red meat, Parmesan cheese and other dairy products. More specifically, dietary supplements such as Whey Amino Acid promote large amounts of this in most cases 11grams total of the essential amino acids as lysine allows

energy to be produced from fatty acids and also to allow the absorbed calcium to grow and develop our bones and muscles.

The absorption aspect of calcium occurs in the intestinal section (Anatomy and Physiology , 2013). The ileum is the last of the three sections of the small intestine is where most absorption of required nutrients and molecules takes place.

The ileum is aligned with several hairs like structures that are known as villi. These hairs like structures allow absorption to take place and increase the surface area so maximum absorption can take place. In terms of calcium being absorbed, receptors on the end of the villi detect the calcium molecules and code for protein synthesis to occur. Lysine is produced as the amino acid and then sent out as a binding protein. The calcium molecule then enters the villi via facilitated diffusion from a channel protein where it then binds to the binding protein and is sent to the membrane of the cell and exits the villi via exocytosis. Once exited from the cell, the calcium then is transported via capillaries to bones or muscle tissues where it then performs growth or repair. This process occurs cyclically where lysine is produced as the required amino acid that allows calcium to be absorbed and allow it to carry out its growth and development on bones and muscle tissue to a large extent.

Collagen Formation (Wikipedia, 2013)

Collagen is groups of naturally occurring proteins found in all vertebrates and are mostly present in the flesh and connective tissues. They can also be used to make fibrous tissues found in ligaments, tendons and skin. More importantly, collagen can be used to form muscle tissues and for the formation of strong tendon muscles.

For collagen to form, transcription and translation in the form of protein synthesis must occur where the amino acid lysine codes for the protein Collagen Fibril.

The first stage in the synthesis of Collagen Fibril is the transcription of the mRNA (messenger RNA) and occurs in the nucleus of a cell. The gene coding for the protein initiates the unzipping of the DNA double helix where free, complimentary nucleotides form a complimentary base pair with the DNA nucleotides. The complimentary bonding between the RNA nucleotides and DNA nucleotides continues until forming a strand of complimentary RNA nucleotides. Once all the required DNA nucleotides have been complimented the mRNA strand in then formed. Once synthesized it then peels off the DNA strand and exits the nucleus into the cytoplasm via the nuclear pores.

The next stage is then pre-pro-peptide formation that involves the process of translation. This is where the mRNA enters the cytoplasm and binds to 2 sub-units of ribosomes that are attached to the nearby rough endoplasmic reticulum. Once attached to the 2 sub-unit ribosomes, methionine is the signal sequence for the polypeptide to be formed.

After methionine has been signaled, arriving anti codons arrive carrying a complimentary amino acid, it then binds to the complimentary codon and synthesizes and peptide chain as more arriving anti codons bind to the mRNA strand forming the peptide chain of amino acids. Once this process reaches the termination codon, the sequence stops and the peptide chain is released from the ribosomes as pre-pro collagen. Next, the pre-collagen is then sent to the Golgi apparatus for one last post – translational modification where oligosaccharides are added to the pro-collagen and is then packed into a vesicle where it is sent out of the cell. This is known as the Golgi apparatus modification. Once outside the cell, the formation of Tropocollagen occurs. This involves membrane bound enzymes called collagen peptidases that remove the (NH3) ends of the pro-collagen molecule where it is now a Tropocollagen.

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After the formation of Tropocollagen, the last step is the formation of Collagen Fibril occurs. This involves the extracellular enzyme; Lysyl Oxidase which acts on Lysine and hydroxylysine's producing aldehyde groups that eventually undergo covalent bonds between the Tropocollagen molecules. The polymer of this Tropocollagen molecule is as Collagen Fibril. Overall, this process is repeated cyclically where collagen fibril protein is produced and is responsible for growing strong muscle tissues. Moreover, with an increased consumption in the source of Lysine found in whey amino acid, collagen fibril protein can be made that can form more fibrous muscles increasing the muscle mass and size to a large extent.

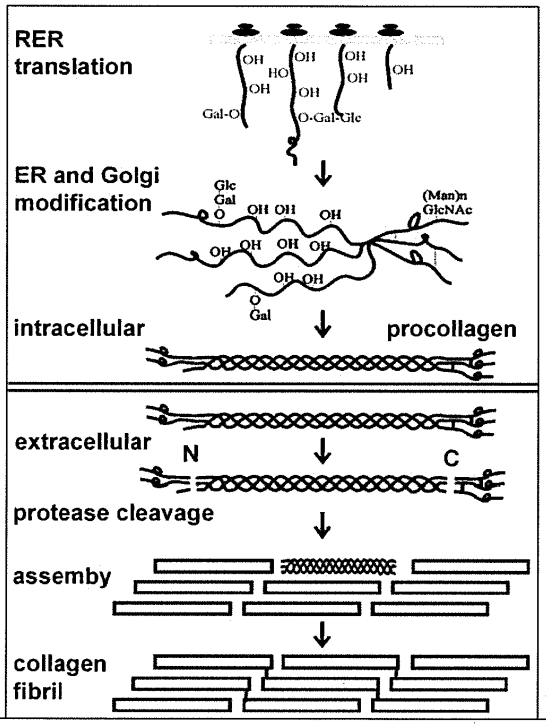


Image 1, showing the process of how collagen fibril protein is formed

http://php.med.unsw.edu.au/cellbiology/index.php?title=Extracellular_Matrix_1

Valine

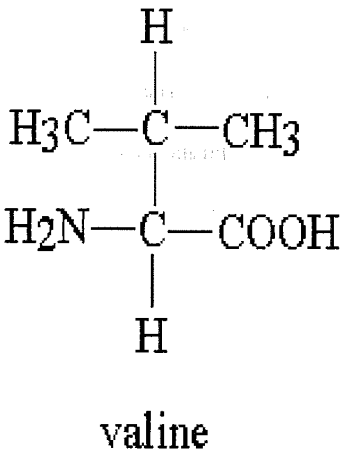
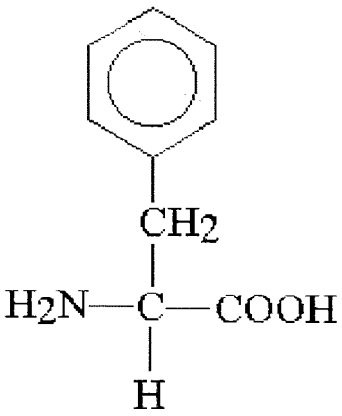


Image 2, http://groups.molbiosci.northwestern.edu/holmgren/Glossary/Definitions/Def-V/Valine.html

Valine, discovered by Emil Fischer in 1901 by hydrolyzing proteins from casein is a branched chain amino acid that provides a stimulant activity. Valine prevents the breakdown of muscle, as it supplies the muscles with an extra source of glucose when in physical activity(Hobbs, No date). Due to its function of being taken up by the muscles and providing an extra source of energy for the muscles, valine is an undoubtedly paramount peptide in providing and maintaining the muscle metabolism and muscle tissue growth. Being a branched chain amino acid, valine constitutes 70% of amino acids in the body's proteins and is found in high concentrations within muscle proteins(Muscle Gauge Nutrition , 2010). Valine promotes an increasing effect in muscle mass and size by providing an extra source of glucose for muscles. Also, stimulation for muscle tissues, metabolism and lastly muscle tissue repair and is found as 5.5grams in whey amino acid. In terms of its role as a Branched – Chain Amino Acid (BCAA) (AminoAcidsStudies, 2013), valine is used to provide the muscles with glucose and in doing so, other glucose molecules can be used for other processes.

From this, by having large amounts of valine in whey amino acid, consumption of valine provides the muscles with an extra source of energy in the form of glucose stimulating muscle growth, muscle tissue and muscle metabolism, overall increasing the muscle mass and size from consumption of whey amino acid to a large extent.

Phenylalanine



phenylalanine

http://groups.molbiosci.northwestern.edu/holmgren/Glossary/Definitions/Def-P/Phenylalanine.html

Discovered by hydrolyzing proteins from casein. Phenylalanine provides a different form of muscle mass and size in the area of amino acids. Although its role primarily allows the synthesis of proteins to form, Phenylalanine has another form itself known as L – Phenylalanine and D – Phenylalanine. L – Phenylalanine and D-Phenylalanine are responsible for the overall health of the human body (University of Maryland, 2013). Once inside the body, these amino acids become the amino acid tyrosine. Tyrosine is responsible for creating vital neurotransmitters such as dopamine, norepinephrine and epinephrine. In terms of its potential to enhance muscle, phenylalanine helps repair damaged muscle tissue during sports or bodybuilding. As short functioned phenylalanine is compared to the other essential amino acids that are present in whey amino acid, phenylalanine provides a balanced function as it provides the well being and health of the body and still manages to repair damaged muscle tissue. Overall, the amino acid phenylalanine that is present in whey amino acid increases muscle mass and size due to its function of forming proteins for repair and to support the body in the required way necessary.

Leucine

Discovered in its impure form in cheese in 1819, leucine is well known for its reputation as 1 of the 3 Branched – Chain Amino Acids and plays a paramount role in its function for repairing and growing muscle tissue (Guide, Leucine, 2013). More specifically, leucine has the ability to stimulate skeletal muscle protein synthesis that allows a greater capacity for the synthesis of proteins and also speeds up the rate at which synthesis occurs. Essential to the body's health and stimulating the regulation of translation in skeletal muscle protein synthesis is the way that leucine allows an increase of muscle mass and size from whey amino acid consumption to a large extent.

Skeletal Muscle Protein Synthesis (Bodybuilding, 2012)

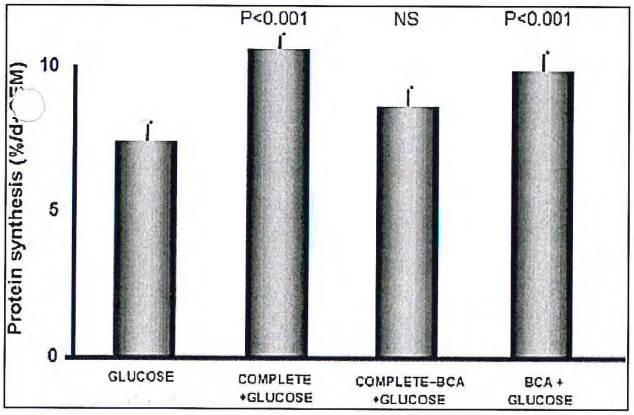
For skeletal muscle protein synthesis to occur, it must go through the basic processes within protein synthesis. These are known as translation and transcription. (See below image for a visual representation.) There are 3 steps in to translation, initiation, elongation and finally termination and is where leucine has its effect on muscle protein synthesis. In initiation the mRNA strand containing the instructions for the protein to be assembled is attached to two sub-units of ribosomes. During the next step of elongation, transfer RNA (tRNA) brings complimentary anti codons and the amino acid and binds to the complimentary codon on the mRNA strand creating a peptide bond between the amino acids. The tRNA continues to bind to the complimentary codon until it reaches a stop codon and the peptide chain is released as an amino acid.

Translation initiation is where the mRNA is combined to the ribosomes is a process that is guided by a group of proteins known as 'Initiation Factors'. Specifically, leucine stimulates the increase of concentration of these 'initiation factors'.

Secondly, an increased concentration of leucine also stimulates a specific ribosomal protein known as 'Protein S6'. This specific protein increases the production of initiation factors and other ribosomal proteins that are essential to protein synthesis. As a whole, the ribosomal protein S6 increases the capacity of a cell to produce more proteins for muscle growth.

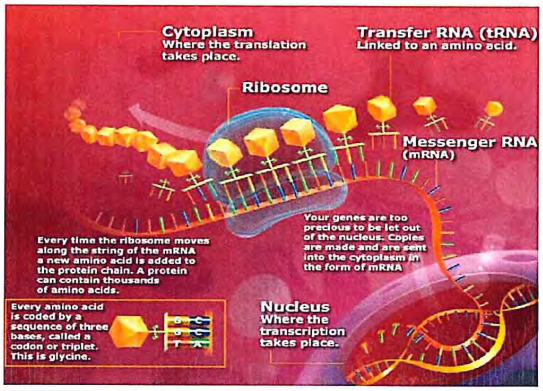
Moreover, leucine does not directly stimulate these processes. In large concentrations, leucine activates the molecule Mammalian Target Of Rapamcyin (mTOR), this cellular machine ends out activating initiation factors ad leads to the increase in the cells capacity to produce more cells needed for muscle growth.

In summary, by having increased concentrations of leucine, this leads to the activation of the Mammalian Target Of Rapamcyin (mTOR) which then allows the cell increased capacity and therefore the ability to produce more proteins needed for muscular growth to a large extent.



ttp://www.abcbodybuilding.com/leucine1.pdf

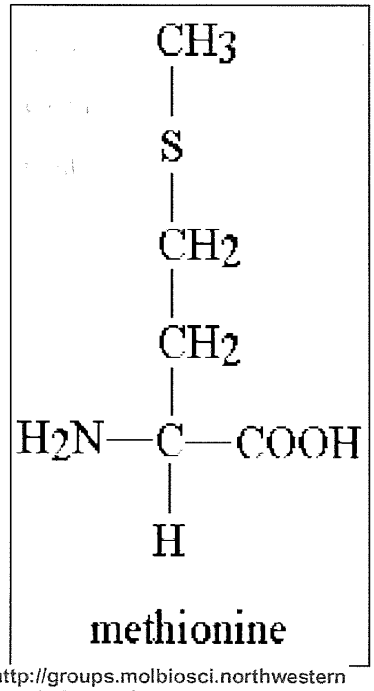
Graph indicating the efficiency rate of which protein synthesis occurs when glucose, complete glucose, complete – BCA + glucose and BCA + glucose are present. Note*= BCA + glucose is leucine and glucose which are present in whey amino acid consumption.



http://www.abcbodybuilding.com/leucine1.

Image to show the process of transcription and translation in protein synthesis

Methionine



http://groups.molbiosci.northwestern.edu/holmgren/Glossary/Definitions/Def-M/Methionine.html

Discovered by J.H. Muller, a researcher in Columbia University in New York in 1922 (Guide, Methionine , 2013). Methionine cannot be produced by the body and instead is found in foods such as, cheese, eggs, fish and meat. Methionine has 3 main roles in terms of its effect on muscle. The first being that it is responsible for the breakdown of fats to reveal muscle, secondly, its codon code 'A-U-G' is the initiation sequence in protein synthesis that creates proteins for muscle growth and lastly, that it has the ability to synthesize into Creatine which is responsible for muscle growth as well (Gertsen, 2012). More specifically, methionine is a sulfur containing amino acid, used to form protein structures in the body. In terms of methionine's role in proteins, its codon in protein synthesis that is Adenine – Uracil – Guanine (A-U-G) is the initiation codon that signals the beginning of the protein synthesis. Moreover, by having large concentrations of methionine, protein synthesis and specifically translation can occur on a larger scale resulting in more proteins created that used for growth and repair of muscle tissue. In terms of its effect on muscle mass, methionine is one of the less influential amino acids for muscle growth, however still provides an essential role in muscle enhancement due to its initiation codon for transcription of proteins to occur. Overall, methionine as its role in the initiating codon for protein synthesis allows the increase of muscle mass and size to occur to a large extent.

Conclusion and Evaluation

Evaluation of Method and Improvements

As conclusive, reliable and valid as this investigation was in identifying the causes of lysine, leucine, valine, methionine and phenylalanine in increasing muscle mass and size, there were some flaws that have been identified in this investigation.

Sample Size

This experiment had only 1 test subject the sample size cannot be generalized. Thus, by having a larger sample size with both genders with a healthy Body Mass Index of 18.50 – 24.99 results, can be more reliable and can be generalized to a larger extent of certainty.

Material for measurement

The measuring equipment was the most limiting factor in terms of the method. By using a tape measure was used and gave accurate results, more accurate and modern equipment could have been used in this investigation to attain a higher level of accuracy. The measuring equipment known as the 'MyoTape' or the 'Orbitape' are examples of measuring equipment that provide a high level of accuracy and are human friendly.

http://www.topendsports.com/testing/products/myotape.html

http://www.topendsports.com/resources/store-product.htm?item=B001RO8IOI&name=OrbiTape

Conclusion

The essential amino acids lysine, leucine, phenylalanine, methionine and valine that are present in whey amino acid consumption do increase muscle mass and size to a large extent. Reasons for this can be seen in that firstly, lysine increases muscle mass and size from collagen formation and calcium absorption. Secondly, it is evident that leucine increases muscle mass and size from its ability to stimulate skeletal muscle protein synthesis. Thirdly, phenylalanine increases muscle mass and size by forming proteins for growth and repair of muscle tissues. Fourthly, the essential amino acid of methionine increases muscle mass and size from its ability to initiate muscle protein synthesis from its codon code, also by burning fats to reveal muscle and finally it is a sub unit of creatine also responsible for muscle growth. Lastly, from the previous pages the essential amino acid valine increases muscle mass size as it acts as an extra source of energy in the form of glucose where additional energy can be accessed for more muscle and skeletal protein synthesis to occur. In addition, to the established reasons as to how these essential amino acids increase muscle mass and size; the processed results can also be an additional source of evidence in the concluding of this experiment. With a high level of accuracy and reliability of the results collected, further confidence and conclusion can be made in that the essential amino acids leucine, lysine, phenylalanine, methionine and valine increase muscle mass and size to a large extent. Lastly, by furthermore increasing the accuracy and conclusiveness of this investigation secondary evidence can be identified in that the essential amino acids in whey amino acid consumption increase muscle mass and size. The 'American Journal of Clinical Nutrition' and 'International Journal of Sport Nutrition and Exercise Nutrition' conducted similar experiments that involved whey amino acid consumption increasing muscle mass and size. Evidence to support this can be seen in

'http://www.nationaldairycouncil.org/SiteCollectionDocuments/education_materials/whey_protein/NDCResearchUpdateWhey2.pdf'. Overall, in terms of the reasons established of how the essential amino acids listed increase muscle mass and size, the results collected and secondary evidence attained, the conclusion that the essential amino acids leucine, lysine, valine, phenylalanine and methionine present in whey amino acid consumption to a large extent can be concluded with a high degree of confidence and accuracy.

References

Picture of Local Gym, retrieved from:
http://www.citygymportsmouth.com/page/gallery

Picture of Protein Shake, Retrieved from:
http://www.myprotein.com/protein-accessories/myprotein-blender-bottle/10485098.html

Amino Acids Guide, (2013) Lysine. Retrieved from:
http://www.aminoacidsguide.com/Lys.html

Anatomy and Physiology of the Gastrointestinal Tract, (2013). Retrieved from:
http://www.tpnteam.com/secure/Glanatomy_physiology.htm

Wikipedia, Collagen Synthesis, (2013). Retrieved from:
http://en.wikipedia.org/wiki/Collagen#Synthesis

Bodybuilding, Leucine, (2012). Retrieved from:
http://www.bodybuilding.com/fun/leucine-build-muscle-with-this-anabolic-amino-acid.html

Amino Acids Guide, (2013) Leucine, Retrieved from:
http://www.aminoacidsguide.com/Leu.html

Hobbs, N.D, How to build muscle with isoleucine, leucine and valine. Retrieved from:
http://www.dummies.com/how-to/content/building-muscle-with-isoleucine-luecine-and-valine.html

Muscle Gauge Nutrition, (2010) Valine. Retrieved from:
http://www.mgnstore.com/valine-page#.Un99lbQu81g

Amino Acids Guide, (2013), Methionine. Retrieved from:
http://www.aminoacidsguide.com/Met.html

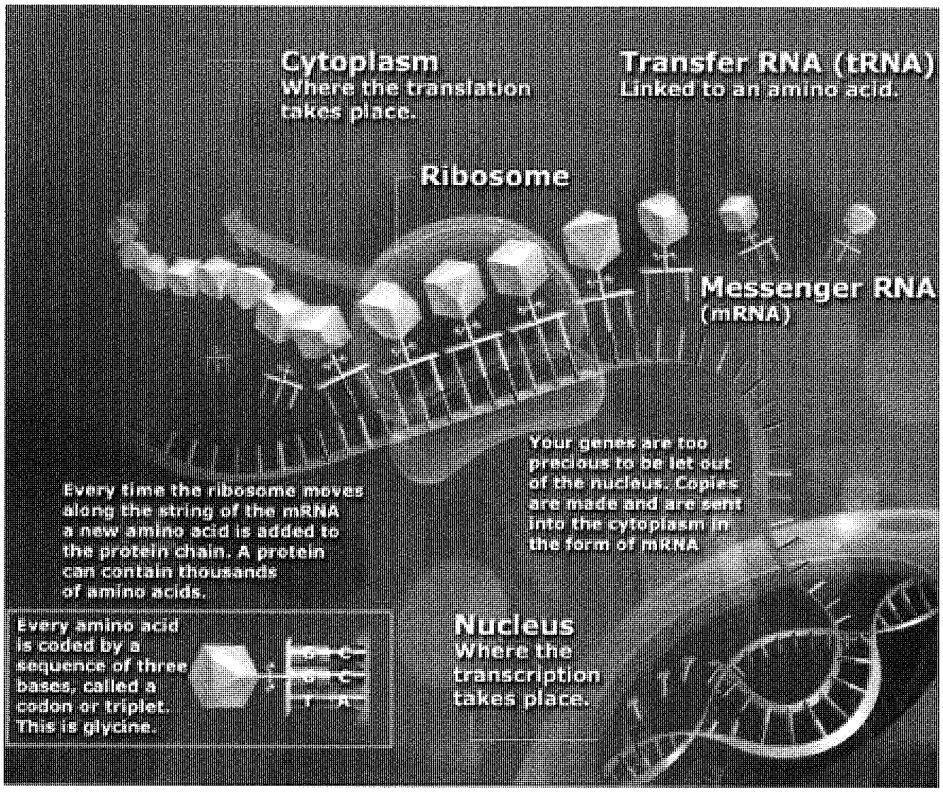
Dr. Gersten, Methionine, (2012). Retrieved from:
http://www.imagerynet.com/amino/20_amino.html#METHIONINE

Amino Acid Studies, (2013) BCAA. Retrieved from:
http://aminoacidstudies.org/bcaa/

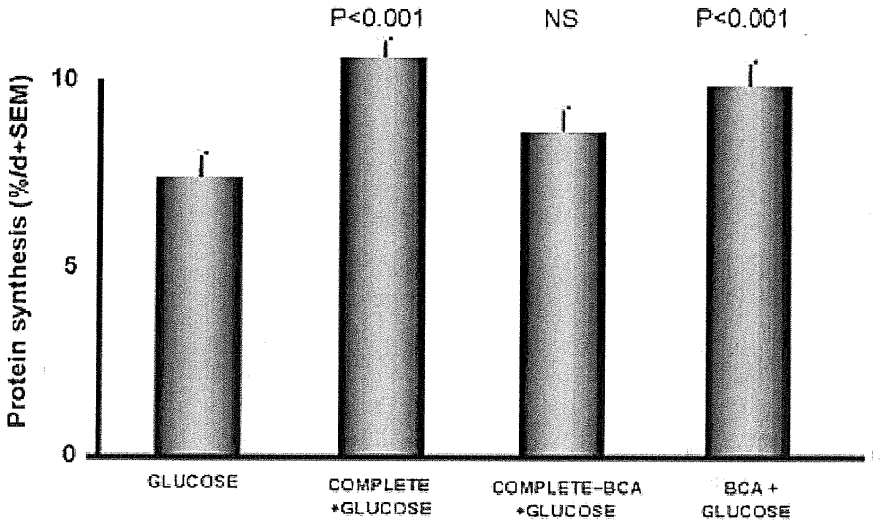
University of Maryland, (2013), Phenylalanine. Retrieved from:
http://umm.edu/health/medical/altmed/supplement/phenylalanine

http://www.nationaldairycouncil.org/SiteCollectionDocuments/education_materials/whey_protein/NDCResearchUpdateWhey2.pdf

Appendix



http://www.abcbodybuilding.com/leucine1.



http://www.abcbodybuilding.com/leucine1.pdf

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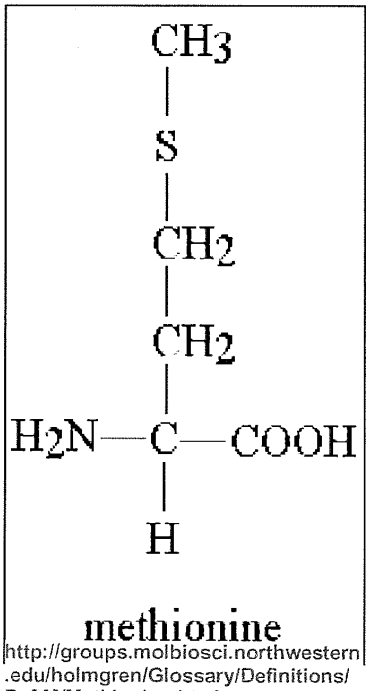
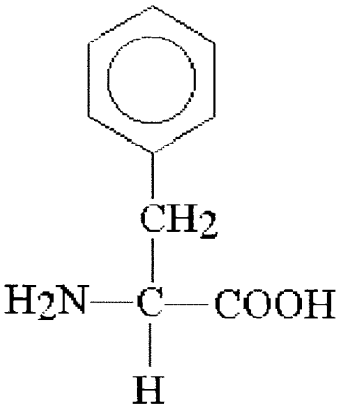
http://www.topendsports.com/testing/products/myotape.html

http://www.topendsports.com/resources/store-product.htm?item=B001RO8IOI&name=OrbiTape



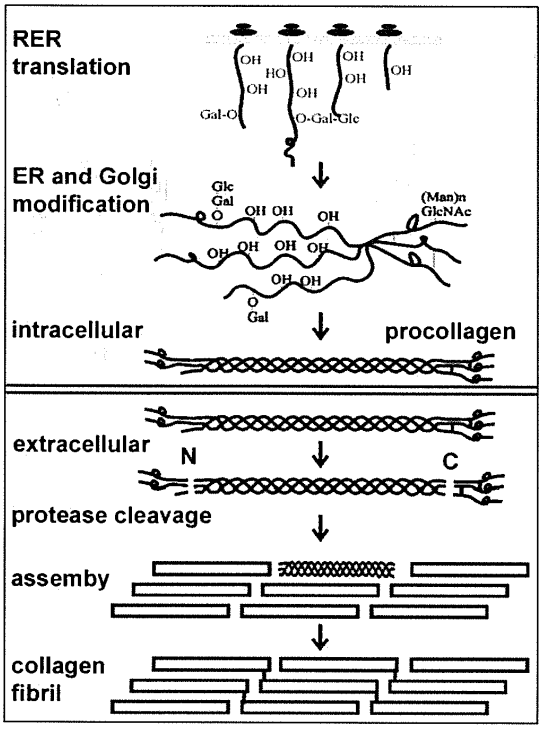
methionine

http://groups.molbiosci.northwestern.edu/holmgren/Glossary/Definitions/Def-M/Methionine.html

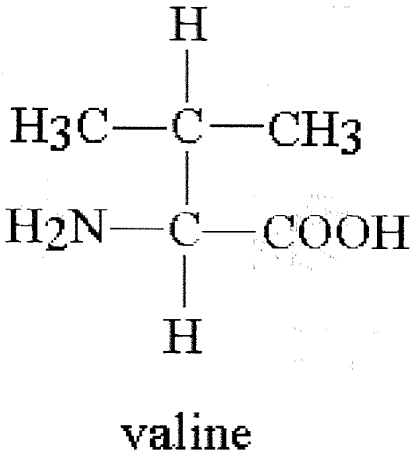


phenylalanine

http://groups.molbiosci.northwestern.edu/holmgren/Glossary/Definitions/Def-P/Phenylalanine.html



http://php.med.unsw.edu.au/cellbiology/index.php?title=Extracellular_Matrix_1



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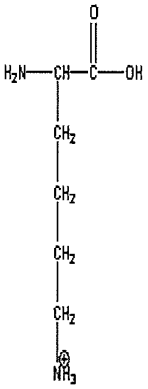

The chemical structure of a lysine molecule.

http://vagabondguru.com/BluePenguinReportDaily/2009/05/amino_acids_proteins_and_bionanotechnology_pt_1.html

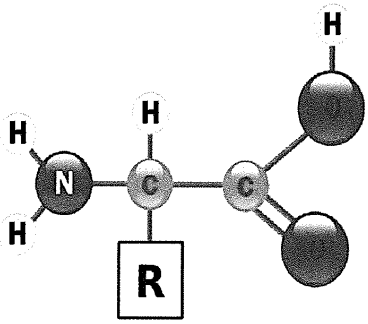

Figure 1, Image to show the structure of a typical amino acid
http://homepages.ius.edu/DSPURLOC/c122/amino.htm

Bibliography

AminoAcidsStudies. (2013, May 4). *BCAA*. Retrieved from AminoAcidsStudies: http://aminoacidstudies.org/bcaa/

Anatomy and Physiology . (2013, March 4). *Anatomy and Physiology of the Gastrointestinal Tract*. Retrieved from Anatomy and Physiology of the Gastrointestinal Tract: http://www.tpnteam.com/secure/GIanatomy_physiology.htm

BODYBUILDING. (2001, April 15). (B. Cat, Producer) Retrieved September 3, 2013, from Bodybuilding: http://www.bodybuilding.com/fun/catamino.htm

Bodybuilding. (2012, March 1). *Leucine* . Retrieved from Bodybuilding: http://www.bodybuilding.com/fun/leucine-build-muscle-with-this-anabolic-amino-acid.html

Gertsen, D. (2012, May 23). *AminoAcids*. Retrieved from Imagerynet: http://www.imagerynet.com/amino/20_amino.html#METHIONINE

Guide, A. A. (2013, May 4). *Leucine*. Retrieved from AminoAcidsGuide: http://www.aminoacidsguide.com/Leu.html

Guide, A. A. (2013, May 4). *Lysine*. Retrieved from Amino Acids Guide: http://www.aminoacidsguide.com/Lys.html

Guide, A. A. (2013, May 4). *Methionine* . Retrieved from AminoAcidsGuide: http://www.aminoacidsguide.com/Met.html

Hobbs, C. (No date). *Building muscle with isoleucine, luecine and valine*. Retrieved from For dummies: http://www.dummies.com/how-to/content/building-muscle-with-isoleucine-luecine-and-valine.html

Muscle Gauge Nutrition . (2010, June 12). *Valine* . Retrieved from MGN: http://www.mgnstore.com/valine-page#.Un99IbQu81g

University of Maryland. (2013, May 7). *Phenylalanine* . Retrieved from University of Maryland: http://umm.edu/health/medical/altmed/supplement/phenylalanine

Wikipedia. (2013, November 10). *Collagen Synthesis*. Retrieved from Wikipedia : http://en.wikipedia.org/wiki/Collagen#Synthesis