Introduction to Exercise Physiology & Sports Performance

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Lecture – 34

Body composition and its Implications (Part -2)

Welcome back to this NPTEL course on introduction to exercise physiology and sports performance into this module on body composition and its implication. You are with me, Wing Commander Chandrasekara Guru. I am a sports medicine specialist and assistant professor in this field with armed forces medical services.

In this module, we will be learning about the different models of body composition, performance and body composition, how are they related. So, this we have covered in the first part. In the second part, we will be going through the assessment methods of body composition and various practices that is involved in body composition globally.

So, let us revise what we discussed in the first part. Body composition, we discussed about the definition, we saw about the evolution of body composition, the various terminologies and various models, the different levels, level 1 to level 5 and how the body composition assessment is utilized in sports, the perspective of that, various determining factors that influence body composition assessment and the existing current evidence relating body composition with sports performance. We also saw on the perceived ideal body composition because of the existing sports culture and the wrong perception that is there, the adverse effects that in an attempt to reach this ideal body composition that leads to abuse of the body, both physical and psychological leading on to health deterioration in terms of relative energy deficiency syndrome and other mental problems including the eating disorders.

So, with this prelude, let us now look into different body composition assessment method. So, there are multiple techniques which are available. There is still no single technique which is universally accepted as a gold standard measure and hence comparison of results between these different methods is challenging because there is no standardized protocol which are available and you need to address this challenge by following or adhering to a proper protocol and utilization of the same assessment method over longitudinal period of time. So, with repeated measures you can use the report to a better kind of benefit to suit your needs.

So, let us see how this body composition methods are broadly categorized based on the utility, based on the measurement technique and based on the models that are used. So, based on the utility you have categorization as reference methods, laboratory methods and field methods. So, obviously with the terminologies reference methods are those which kind of used as a reference standards like cadaveric method which is no longer being used because of the ethical consideration. Laboratory methods, say which are used predominantly in the lab and they are more you know costly and there may be some limitation with respect to that. Field methods, obviously are utilized in the field they are more user friendly but however they have certain limitations. With respect to the measurement techniques, you have if the assessment method directly measures the body composition, then it is a direct method. It uses some methodology

by which it directly measures. Say, for example DXA, DXA scan directly measures your bone mineral content. So, bone mineral content is the direct output of you know DXA. However, the other parameters of body composition like body fat percent or the lean body mass they are derived indirectly based on the direct measure. So, this is a indirect method. There are methods which have doubly indirect methodology in assessment. Say, they use a certain equation by assuming certain parameters, and that is a doubly indirect method. Say, for example, assessment of body composition using skinfold thickness. It is a doubly indirect method. Based on the models that are being used, it can be two component model like fat mass and fat-free mass, three component model like fat, bone, and lean body mass, a four-component model, bone, muscle, and other tissues including the adipose tissue. So, based on the models you have different types of body composition assessment.

Further, the body composition analysis from the utility aspect we will further go in detail. So, with the reference methods have cadaveric dissection method, multi-component model method using the chemical as well as the anatomical methods. Then you have the medical imaging like MRI and CT derived, you know, references on body composition. When focusing on lab methods, the predominantly used lab methods in the field of body composition assessment are DXA that is Dual energy X-ray Absorptiometry, is more of a medical imaging technique which is used. Then you have the densitometry. Then you have 3D photonic scanning. Field methods which are widely used across the globe are anthropometric method using the ISAC standard. ISAC stands for International Society for Advancement of Kinanthropometry. So, the anthropometry methods as suggested by ISAC is one of the commonly used, you know, methods across the globe in the field especially in those who are involved in the sports. Bioelectrical impedance analysis method which uses the electrical bioelectrical impedance method to identify the body composition based on the body water. Then you also have ultrasound-based body composition assessment based on the subcutaneous adipose tissue and the skin thickness. Based on that you also have body composition assessment methods. When we look at the densitometry, the traditional methods have been in the lab, have been underwater weighing and off-late we have instead of water we use air as a displacement plethysmography. So, that is the air displacement plethysmography. Off-late you find an increase in the number of research articles on this particular method using, you know, something called as BOD-POD which is commercially available.

So, which method is prevalent across the globe? It is very important to understand that so that we focus on those methods in detail to have a basic idea about these methods and their implication in sports. So, as you can see in this graph, this data has been, you know, taken from the open-source data. It's been done by survey by the International Olympic Committee on the body composition methods. So, based on the questionnaire they have given this data this is an open access data available online. So, based on that I have just charted the, you know, based on the utilization of body assessment method. So, if you see the bars on the blue represent the survey answers for these questions when it was considered in 2013 almost 10 years back and the dark, you know, maroon color denotes the survey results which is conducted as recently as December 2022. So, this also gives a decadal change in the usage and the prevalence of the body composition methods across the globe. So, let's focus on the graph, the x-axis gives you the different body composition methods and then along the y-axis you have the percentage. The respective percentages are mentioned here on top of the bar. So, the blue bar represents the reported measures in 2013, and the red one measures in 2022. So, it is very clear that you see

there has been a definitive increase in the utility of body composition method in terms of ISAC recommended anthropometric measure and the use of DEXA scan for body composition assessment. And the bioelectrical impedance analysis has been used, and it's been almost the same as per the utility wise. So, these three are the most prevalently used body composition assessment methods in sports globally. In addition to that, if you see there has been a drop, in fact a drastic drop, from 48 to 8, only in using skin folds using body composition analysis using skin folds using various formulas to estimate the body fat percentage. So, this clearly shows that the shift is here from year to year because of the standardization aspect of it. So, with this prelude, I think we can proceed further.

So, we will see about these three body assessment techniques subsequently. So, coming to the anthropometry skin folds technique as recommended by the ISAC. It is a common field method. Why is it gaining popularity? Because of the standardization that the ISAC has brought in, and it also gives a certification for that and with some validity. So, individuals have to re-certify and re-validate. So, that's important in terms of updating about the existing standardization as per the existing evidence. The method per se it is an indirect method; it uses the skin fold sum and skin fold ratios to derive at body composition parameters. It uses doubly indirect method for arriving at these parameters of body fat and fat-free mass using certain regression equations. So, if you look at the precision of this particular method, precision means what you can say the repeatability when you repeat again what is the difference. So, it is generally seen that the error which is expected between an ISAC trained measure is only 5 percent. So, this is okay, and the caution that one needs to keep in mind when you use this method is that there are several assumptions. So, it's a doubly indirect. So, it assumes that the skin compressibility, skin thickness compressibility, and the skin adipose tissue compressibility are all constant, but there would be definite variation between individual and within individual at different sites. So, that's one of the assumptions that this method has. So, the limitations are only the measurement technical estimate of the measurement or technical error of measurement (TEM) is estimated to be 5 percent only if the individual is a trained measurer from the ISAC. So, you definitely need the training that is mandatory to undertake this particular assessment. It can be intrusive for some individuals because you use a particular type of calliper to measure the skin thickness and skin fold, and certain athletes may not or certain individuals may not allow you to kind of take a pinch of the skin and then measure the thickness. So, that may be intrusive for that individual. It only measures at certain fixed sites. So, it is only corresponding to the fat or the subcutaneous adipose tissue deposition in that area and that particular site. So, that is again kind of generalized to arrive at the total body fat percent. So, it is again the limitation and as a point of kind of procedural thing, when you do assess using this method, there may be certain sites where you will not be able to take a clear pinch where you can measure the skin fold thickness. So, these are certain limitations, but still the advantages weigh far too much than the limitations, that it is globally gaining so much of popularity because it is a field method, can be utilized anywhere. The protocols are standardized by ISAC, and there are already norms available for these equations and for different age, gender, and ethnic groups. So, that makes it easy for having reference values. More importantly, it is only superficially you are doing so, it is a non-invasive method, and it does not involve any radiation, and the change that we speak about gets minimally affected because of the previous exercise before the measurement or by hydration status or by the food intake, which is actually a major kind of requirement or a prerequisite in other body composition assessment methods. More importantly, it is cost-efficient, so the calliper is the only cost or the tape that you would be

using. Just as things are the equations, with the help of equations we can easily calculate them. So, the point that I would like to carry on is that the anthropometric ISAC certified thing is gaining popularity because of the standardized method that ISAC has provided and also the regular training and the continuing training for that certification which it has introduced. And more so, it is a very low-cost methodology to assess the body composition and hence it can be easily used in the field without any prerequisites, there are no major prerequisites, so because of which it is gaining so much of popularity.

So, the next another method of lab method I would say for estimation of body composition assessment of body composition is using dual energy x-ray absorptiometry, that is DXA. It is a it is a lab method directly it uses its method technique to assess the bone mineral content, so based on the input and other algorithms that are available, it also indirectly measures the fat mass and the lean body mass. So, the accuracy of body fat percentage varies anywhere between two to three percent as of the standard error estimation. The caution that we need to remember here is that there are protocols but then the standardized protocols vary with respect to the manufacturers and for calibration of this equipment the animal models are used. So, obviously this difference between the human live human body composition and the animal models and hence there is a correction factor that is used, the correction factor also for the indirect measure as a separate correction factor for the soft tissue composition. So, that's again the thing that one needs to remember, so limitations that we have is that it has some amount of radiation, so with single exposure the radiation is acceptable range whereas with the serial kind of longitudinal assessment the cumulative radiation increases. So, obviously in pregnant athletes or pregnant women you will not be able to use this modality for assessing body composition and the initial capital cost and the equipment and the maintenance aspect is very high so it's very costly. And you may also have lot of variation with respect to the indirect measures of soft tissue calculation because the algorithm is involved and also in case of lean individuals because of the very less amount of soft tissue there may be a difference in the calculations there may be some measurement errors. So, the advantages despite of these limitations still it is one of the preferred lab method for body composition assessment because it gives you three different models. So, three model assessment can be done it gives you fat mass it gives you the lean body mass as well as the bone mineral density. So, with this you have three different component ranges most of the protocols as per the manufacturer instructions they're all standardized. So, and again because of the wide usage you have norms that are available for bone mineral density and then the body composition is still there's no clear-cut norms that are available it's an additive factor to the usage of the equipment. And another important example is the important advantage is that it uses a whole body approach so entire body is screened so based on the availability of the software and the calculation you can also have segmental distribution of the these body parameters and it takes very less time so time efficient obviously so you can do it in mass and the precision factor is good for bone mineral density. So, as I said you can also have regional compartment-based analysis using the software and the single scanning does not have much of a radiation exposure. So, to the crux of this particular slide is that it is a recommended lab method and if follow a best practice protocol since most of the places have best practice protocols in you know instituted in these centers and the interpretation can be made have to be made with the limitations that have been mentioned especially with respect to the soft tissue calculations.

The third method which is again a prevalently used method since almost there's not much of change with respect to the last decade survey that is the bioelectrical impedance, it is commonly used field method, why it uses the indirect method wherein it assess the body water using low amplitude painless current and based on the tissue resistance it provides you the body composition factors so based on the total body water you assess indirectly the body fat percentage and fat free mass percentage based on the equations. The accuracy is slightly higher, on the higher side, in the sense the variation is more error, error effect is more, error estimation is more for body fat is 3.6 percent for fat free mass, it is about 2.5 to 3 percentage 3.9 percent, in fact. They have the caution is that it has a lot of assumptions which is already made that unusual is complaint to the prerequisites, a lot of strict prerequisites that are required, and you assume that the individual has strictly adhered to whatever the instructions that you have given, and it also considers see the human body as a lot of you know control, changes, and variations. But in this case, we consider the entire human body as a geometrically similar cylinder kind of a thing, so obviously that has an assumption, and that assumption factor has some error also, and it also considers that the tissue resistivity, which is mainly used to come at the conclusion of identifying the body fat and the body mass parameters, it assumes that all the tissues have same resistivity, but again it varies with respect to the muscle mass and the fat mass. It also is highly dependent on what you, what the data you input. So, there are various types of level of physical activity that you will have to choose, you will have to include input the height as well as the weight parameters, and you will have to choose the right equation for the level of activity of that individual. So, all these factors are dependent on the knowledge of the measure and what the individual actually gives input to the particular method or the equipment. So, despite these limitations, the advantage is that the precision is high, so the accuracy is the error is more, however, the precision if you see the precision is high. Precision in terms of precision would be repeated measurements are good in an individual, and the it is portable, so battery operator can be used on the field, it is non-invasive, user-friendly, very minimal subject involvement during the recording, there's no ionizing radiation that is used or you know acquired during the process, the data acquisition is quick and immediately you can have a report which is more of a sophisticated, good-looking report can be generated.

So, standardized conditions are required. These are placing of the electrode is again has to be standardized, the different models that are available, multi-electrodes, dual-electrodes, so these needs to be accordingly carried out as per the manufacturer instructions, so there needs to be standardization in terms of electrode placement, subject's body position is important, hydration status of the individual, since the method uses body water, so the body water is basically dependent on the hydration status, so that can have a completely different you know output if the hydration status is not maintained. It also has influence by the food that you intake before the assessment, also depends on the skin temperature where the electrodes are being placed. So, these, and also the latest or recent exercise if the individual has done that would also affect the hydration status in turn also can affect the body water status, so that can affect the results of the study as well. So, in order to have a standardized report and avoid this variation in the report because of these situations, you need to have a clear-cut three you know requisites or the instructions that needs to be followed before conducting this test. So, the individual has to be advised to avoid alcohol at least eight hours before the test. Individual should undergo the test in fasting condition to avoid that influence of food. Drink no water four to six hours prior to the test to maintain the same hydration status, avoid any tea or coffee again which can hamper your hydration status. Avoid any physical activity on the previous day to maintain the same

level of body water composition in the compartments. Also, because we use low amplitude current, all the metal items have to be removed from the individual before doing the test, and the position of the patient has to be standardized. If you are doing in a four electrode multi component bioelectrical impedance equipment, then the individual has to be supine with arms at 30 degrees of abduction and the legs at 45 degrees of abduction, so that gives a standard position of the patient or the individual whom you are going to measure.

Coming to the limitation of this method is that accuracy, as we discussed, is poor was the large you know standard error estimation, then the it has depended on so many factors including the hydration status, like it depends on the age, gender, ethnicity, the hydration status as we discussed, the nutritional you know effect in terms of the nutritional status of the individual, obesity as well as the malnutrition status can also have an effect. In addition, these are all mainly equation based, so it is important to have the same set of equation or equation should be chosen as per the physical activity level of the individual, and as per the different training phase in which the individual is, so accordingly the interpretation of the values has to be made by the concerned measurer or the interpreter, and since across the globe there are so many different types of equipment based on biological impedance are available in the market, there's no proper standardization of the protocol, so it is difficult to compare and have a normative values, the large variability because of these many devices and the equations used and the equations per say the there's not much of athletic specific equations that are available at present. So, to summarize the bioelectrical impedance method of body composition, it's a easy to use prevalent used field method, however it has a large gap in terms of accuracy, however, can be used for following up longitudinally, so you have you can take this you know before the onset or starting of the season, and then continuously at periodic intervals, you can measure using the same equation, same set of standard protocols, and that gives you good precision for following up, that is important, and also standardization of the condition as well as the equipment and the position with the prerequisite instructions will improve the results of the body composition parameters.

So, how frequently, how frequently should we do a body composition assessment in case of athletes. Say, again during this survey by the IOC it was found that the frequency has been now kind of more towards four times per year. Earlier if you see there was no option for this others the too many people commenting on others, however, predominantly there's not real consensus, so somewhere even saying every four weeks it needs to be done. So, over 10 years the shift of this opinion has changed, wherein predominantly now people are kind of recommending four times per year, that is at least quarterly assessment, so that you have body composition assessment every quarter as per the planned macro cycle. So, if you have an annual macro cycle, you can do the body composition just before the start of the, you know, meso-cycle. We have four meso-cycles, so just before the starting of the meso-cycle, you can address this, so you can have a longitudinal follow-up based on the training parameters and the other performance parameters that you assess. So, generally it is not a specific only that body composition is being analyzed, generally it is clubbed with the other parameters that are being analyzed for performance enhancement, so that's an important aspect that one needs to understand.

What about the cutoff values? So, I initially in my part one of this body composition I have brought out certain body fat percentage values, but that was for the general population, right. So, what about the cutoff values if you use different body composition methods? So, in this

survey there were questions based on this minimal and maximum value for both males and females, so if you attend to this particular, if you pay attention to this particular table, you find that we focus on body fat percentage, body fat percentage for males, okay. So, in males in 2013, the minimal value was four to ten percent the range, and now this minimal value has now got down to six percent, so there is an increase in the minimal value if you see here, and with respect to the females if you see it was nine to fifteen percent, now the survey respondents have predominantly said it should be twelve percent, so that's an important aspect that there's a change that the minimum level that is required for particular sport has now increased for both males as well as females, that's in in fact it's a very good sign that we are moving away from that ideal perception of ideal body composition thing, then you come about the maximum level, maximum level is there's not much of response with respect to this, because probably that it depends on the particular sports that is involved, so that is one aspect of change that has happened in body fat range, then ISAC anthropometric model being the most commonly used is some of eight skin folds as a range, when we see in 2013 again the range was 80 to 120, now the range as now rather in the minimum level, the range has now been fixed to 12 mm and 25 mm for males and females as compared to 2013 where it was given as a range earlier, so the range was given earlier, now that has now got fixed to a minimum required only, so these are the two important points with respect to the cutoff values in respect to the body fat percent using the body composition.

So, one interesting thing is you should ask for a body composition analysis, whether the athlete or whether the coach or it should be the performance director or it should be a sports physician or it should be a sports dietition who should be requesting for a body composition analysis. So, again interesting this survey found that there's a vast difference in terms of those who requested for body composition analysis, ten years back and today, so if you see that predominantly now, it is from the sports medicine and sports science, scientific group or the rather the performance you know high performance team who is responsible for the athlete have requested for the body composition assessment. So, obviously we presume that this team have, you know, adequate scientific knowledge about the analysis and the assessment of body composition, and that's a positive change that has happened. And you see, however, the athlete also has started taking ownership about their body composition wherein the request has been predominantly now has increased from the athlete side as well. The coach request has been almost the same. Now even the therapist during incorporation of their strength and conditioning activity, as well as the physiotherapist post-injury rehabilitation, have been using the body composition outputs for better giving better benefit for the rehab program or for the strength and conditioning training aspect per se.

So, that's about who requests. Then another question comes to what is the practice of who is measuring the body composition. So, that is also an important aspect that needs to be considered considering there is no single method which is more accurate in measuring the body composition. So, in that case, again, the survey found that you find sports nutritionist or dietitian have been doing the body composition on their own. So, body composition is being done also or measured by the sports nutritionist and dietitian, which is a very, very good positive sign, and with predominant of this measurement is done by the performance team, those who have some expertise in terms of doing the activity. So, that again improves the accuracy level as the standardization of this. So, and more importantly, you see there is an also

increase in the measurement done by the performance coaches as well or the head of the performance as well. So, it's again a very good sign.

What about the standardization strategies that's being followed globally? There is a definitive increase in the standardized regularized protocol that we have seen in terms of an ISAC recognized anthropometric measurement. So, people recognize a protocol which is already been established and proved. So, that's one thing, and you have people measuring using trained measures so that the standardization with respect to the measurement-related things are negated and the pre-testing conditions are more stringently followed before the testing of body composition. So, obviously, there is a decrease in the same measure and the equipment that is being calibrated. So, that's an important positive change it's happened over 10 years.

So, to summarize, we saw about various categories of body composition, the methods that are available, how they differ with respect to the utility in sports setup, the prevalence of these methods predominantly in terms of the field method and the lab method. We discussed each of them, and we saw also the cutoff values and the frequency at which this body composition is being done. We also found how the world is shifting in terms of who needs to request a body composition analysis for an individual and who measures and what kind of standardization strategies that the people involved in the sports field follow across the globe.

For further in-depth reading, you can refer to these standard textbooks and to this article which is available online as an open-access article in the British Journal of Sports Medicine published by the International Olympic Committee of Medical Commission.

Thank you.