METHOD FOR MEASURING GOLF SWING EFFICIENCY

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ABSTRACT

A method and apparatus for determining the efficiency of an athlete’s body movement is disclosed. With particular reference to the sport of golf, the present invention relates to measuring the ground reaction forces of a golfer during a golf swing. The ground reaction forces may be resolved into a single value. At the same time, the dynamic characteristics of the golf club are also measured, including the golf club head velocity. Comparing the single value to the club head velocity allows the golfer’s efficiency to be determined. The efficiency may be used for a wide variety of purposes, including fitting golf equipment, technique improvement, and fitness assessment.

<table>
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<tr>
<th>PLAYER</th>
<th>MEAN TORQUE (N m)</th>
<th>ANGULAR IMPULSE (N m s) M(t)dt</th>
<th>DURATION OF TORQUE APPLICATION (s)</th>
<th>DURATION OF TORQUE APPLICATION (%)</th>
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<tbody>
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<td>B</td>
<td>13.82</td>
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<td>C</td>
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### FIG. 1

<table>
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<tr>
<th>PLAYER</th>
<th>MEAN TORQUE (Nm)</th>
<th>ANGULAR IMPULSE (N m s)</th>
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### FIG. 2

<table>
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<tr>
<th>PLAYER</th>
<th>MEAN FORCE (Nm)</th>
<th>IMPULSE FORCE (Ns)</th>
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### FIG. 3

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<th>MEAN TORQUE (Nm)</th>
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<td>A</td>
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**FIG. 4**

<table>
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<tr>
<th>PLAYER</th>
<th>CLUB HEAD VELOCITY (m/s)</th>
<th>CLUB HEAD MOMENTUM (kg m/s)</th>
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<tr>
<td>A</td>
<td>49.84</td>
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<td>C</td>
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**FIG. 5**

<table>
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<tr>
<th>PLAYER</th>
<th>MOMENTUM EFFICIENCY RATIO (IMPULSE FORCE / GOLF CLUB MOMENTUM)</th>
<th>ANGULAR MOMENTUM EFFICIENCY RATIO (ANGULAR IMPULSE / GOLF CLUB MOMENTUM)</th>
<th>MEAN FORCE (N)</th>
<th>MEAN TORQUE (N m)</th>
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<tr>
<td>C</td>
<td>12.6</td>
<td>2.2</td>
<td>95.07</td>
<td>17.57</td>
</tr>
</tbody>
</table>

**FIG. 6**
METHOD FOR MEASURING GOLF SWING EFFICIENCY

FIELD OF THE INVENTION

[0001] The present invention relates to a method for measuring golf swing efficiency. More specifically, the present invention relates to analyzing individual golf swings based on the kinematics of a person during athletic motions and the dynamic characteristics of a piece of equipment in motion.

BACKGROUND OF THE INVENTION

[0002] The movement of an athlete’s body is of paramount importance in nearly every sport. Often this is because the correct movement of a piece of athletic equipment is dependent on an athlete using proper form or technique. This is especially true, for example, in the sport of golf. Despite an athlete’s brute strength, the proper trajectory of a golf ball cannot be achieved without first mastering the proper technique for swinging a golf club. The correct swing, in turn, depends on careful coordination of the movement of the entire body. Improper movement, or even timing of the movement of a single body part can cause the golf club to be swung in an undesirable manner.

[0003] Golfers collectively spend millions of dollars each year attempting to fine tune each aspect of their game. For both professional and amateur golfers alike, equipment can often be a key to success. To satisfy the demand for equipment while accommodating the different body types, swing mechanics, and varying levels of skill, golf equipment manufacturers have produced equipment that is limited only by the imagination and the requirements of the United States Golf Association (USGA).

[0004] Many golfers select equipment such as clubs and balls arbitrarily, or based on questionable advice. More savvy golfers may research different types of equipment and/or seek the help of qualified golf professionals. The advice of both of these categories of people, though well intentioned, may be subject to human error. To provide a more accurate method of recommending golf equipment to a golfer, equipment manufacturers have developed machines, known as launch monitors, that can automatically monitor a golfer while they swing a golf club and strike a golf ball. Launch monitors typically acquire several high-speed images of both the golf club and golf ball, and determine the dynamic characteristics of each. By monitoring the golfer using different types of equipment, a launch monitor can provide a quantitative analysis of a golfer’s performance with each type of equipment, easily allowing the most suitable equipment to be recommended to the golfer.

[0005] Despite the ability of a launch monitor to quantify the motion of the golf equipment near or at impact, a continuing need exists for a method and apparatus that monitors and quantifies the movement of an athlete’s body, which, as mentioned above, can often be crucial to proper movement of sports equipment. A continuing need also exists for a method and apparatus that can monitor an athlete’s body and accurately compare this movement to the dynamic characteristics of the athlete’s equipment. Further, a need exists for a method and apparatus that uses the comparison of the dynamic characteristics of the athlete’s body and equipment to assist in recommending equipment, technique improvement, and fitness assessment.

SUMMARY OF THE INVENTION

[0006] To overcome these and other disadvantages, the present invention comprises a method for determining the dynamic characteristics of a golfer. The method includes determining force components, e.g., in the x, y, and z directions, of a golfer’s body transmitted through each of the golfer’s feet. A resultant force is preferably determined based on the force components. At substantially the same time, the club head impact velocity of a golf club swung by the golfer is also determined. The resultant force is then compared with the club head velocity of the golf club. It is desirable for the force components to be measured as a function of time.

[0007] According to one embodiment, the resultant force is determined by correcting the force components to account for the weight component of the golfer, and combining the corrected force components to yield the resultant force. The present invention may also comprise determining a moment for the golfer about a vertical axis. Alternately, the average force and torque for at least one of the following time durations is determined: a time from an initial club take away to an impact with a golf ball; and a time from a start of a downswing until an impact with a golf ball. Additionally, the average force and torque may be determined for a time from the initial club take away to the top of the golfer’s backswing.

[0008] The method may also include determining a club head momentum using the club head velocity. An efficiency ratio may then be determined by integrating the impulse force and comparing it to the club head momentum. The method may also include using the force components to determine a resultant moment, as a function of time, about a vertical axis passing through the golfer’s body. An angular impulse may then be determined based on the resultant moment. Optionally, an angular moment efficiency ratio based on the angular impulse and the club head momentum may also be determined.

[0009] According to another aspect, the present invention comprises an apparatus for determining the force dynamics of a golfer. The apparatus includes a force plate selectively positioned beneath a golfer’s feet, a camera for acquiring one or more images of a golf club, and a processor operatively connected to the force plate and the camera. The processor is operable to compute resultant forces from the force plate and a golf club head velocity from the one or more images of the golf club. The processor is preferably operable to compare the resultant force to the club head velocity in order to determine swing efficiency. To assist in assessing the efficiency, the resultant force is used to determine various stages of a golf swing including backswing, downswing, and follow through. It is desirable for the resultant force to comprise a single value computed from the force components of each of the golfer’s feet.

[0010] In this embodiment, the force plate is operable to measure force and torque components of each of the golfer’s feet. Based on the torque components, the processor is operable to determine the moment of a golfer’s body about an axis. The force plate may preferably comprise first and second force plates. It is desirable for the first force plate to be configured and dimensioned such that it is selectively positioned under a first foot of the golfer, and the second force plate is configured and dimensioned such that it is selectively positioned under a second foot of the golfer.

[0011] According to another aspect, the present invention comprises a method for measuring the dynamic characteristics of an athlete. The method includes determining force components transmitted through an athlete’s feet. The force components may then be used to determine a single value representative of the athlete’s body movement. At substantially the same time, the dynamic characteristics of a piece of equipment manipulated by the athlete are also determined. Then, the single value representative of the athlete’s body
movement is compared with the dynamic characteristics of the piece of athletic equipment.

[0012] In this embodiment, the efficiency of the athlete’s body movement is preferably based on the single value representative of the athlete’s body movement and the dynamic characteristics of the piece of athletic equipment. In alternate embodiments, however, it may be desirable to determine the dynamic characteristics of a body part of the athlete. This may be desirable, for example, to compare the athlete’s body movement to the movement of a particular part of their body, e.g., an athlete’s hand movement when throwing a football.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Further features and advantages of the invention can be ascertained from the following detailed description that is provided in connection with the drawings described below:

[0014] FIGS. 1-4 are tables showing dynamic characteristics for three exemplary players according to one aspect of the present invention;

[0015] FIG. 5 is a table showing an exemplary club head velocity and momentum at the moment of impact between the golf club and the golf ball in one embodiment of the present invention;

[0016] FIG. 6 is a table showing efficiency ratios for three exemplary players according to one aspect of the present invention; and

[0017] FIGS. 7-12 are graphs that display exemplary forces and torques generated by three different golfers according to one aspect of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] The popularity of golf has increased substantially in recent times, has as the number of golf courses available to the amateur golfer. The varying degrees of skill of these recreational players has lead golf equipment manufacturers to produce a variety of equipment product lines. To assist golfers in choosing from the different types of products, equipment manufacturers have come up with a variety of ways to determine which type of equipment, e.g., balls and clubs, fit a particular golfer. The type of equipment that suits a golfer typically depends on factors such as height, weight, the golfer’s ability or degree of skill, swing speed, golfer preference, and the like.

[0019] Rudimentary methods of matching golfers with equipment involved having a golf expert, e.g., a golf instructor, observe a golfer while they used a variety of types of equipment. Based on these observations, and other factors, e.g., the resultant trajectory of the golf ball, the golf expert would suggest the most appropriate equipment for a golfer. This method, of course, is subject to human error and may have questionable accuracy. To overcome these disadvantages, equipment manufacturers began to use launch monitors. Typically, a launch monitor has a field of view within which a golfer positions himself/herself. When the golfer swings a golf club and strikes a golf ball, the launch monitor is able to determine several aspects of the dynamic characteristics of the golf club and ball. Launch monitors are well known to those skilled in the art.

[0020] To further improve on the launch monitor concept, the present invention provides an apparatus and a method for monitoring the dynamic motion of an athlete’s body, in addition to monitoring the dynamic characteristics of the equipment that they are using. Preferably, this is accomplished by measuring ground reaction forces produced by the athlete’s body as a function of time. Using the ground reaction forces, a correlating impulse force may be generated. The impulse force provides a measurement of the work done by the athlete during the athletic motion. Comparing the generated impulse force with the dynamic characteristics of the equipment, which is measured at the same time, provides insight into the efficiency of a player’s movement, e.g., a swing of a golf club.

[0021] As mentioned above, one aspect of the present invention relates to the sport of golf. In particular, the present invention may be used to assist a golfer in fitting golf equipment, technique improvement, assessing their physical fitness, and the like. The ground reaction forces may be measured in several manners, using a variety of equipment. The ground reaction forces are preferably determined by measuring the forces and moments (torques) transmitted through the feet to the ground during athletic motions.

[0022] The present invention may be implemented in combination with a processor or a computing device that includes a processor. The processor may be operatively connected to a variety of elements including, but not limited to, a memory, e.g., Read Only Memory (ROM) or Random Access Memory (RAM), a display, e.g., a CRT or LCD screen, input devices, e.g., a mouse or keyboard, and a bus, e.g., Universal Service Bus (USB). Skilled artisans will recognize that other elements may also be operatively connected, such as wireless cards for Internet or other data network connectivity, printers, and the like.

[0023] In one embodiment, the ground reaction forces may be measured using an electromechanical device, such as one or more force plates, that are positioned on the ground. The force plates are preferably operable to measure ground reaction forces of a person who is standing on them. Preferably, there may be only a single force plate for both feet. In other embodiments, there are two force plates, one selectively positioned underneath each foot. Alternately, there may be more than two force plates, e.g., two or more force plates under each foot. In this embodiment, one plate may be selectively positioned under the heel of one foot, while another plate may be selectively positioned under the ball of the same foot. One example of a force plate that may be used is manufactured by Advanced Mechanical Technology, Inc. In other embodiments, however, any force plate known to those skilled in the art may be used.

[0024] According to an aspect of the present invention, the ground reaction forces are determined by measuring the force components, e.g., in the x, y, and z directions, for each of the golfer’s feet. The components are then preferably combined to yield overall resultant force components. As will be appreciated by those skilled in the art, the weight of the golfer will result in a force component in the direction of gravity, e.g., the z axis. In order to correct for this discrepancy, the weight of the golfer is corrected for in that direction.

[0025] In one embodiment, several force measurements may be calculated. For instance, it may be desirable to calculate the mean force for a golfer. The mean force may be measured in Newtons in one embodiment. It is desirable for the mean force to be determined for different portions of the golfer’s swing, e.g., from initial take-away of the club until impact, or from the start of the downswing to impact. Alternately, other swing intervals may be selected to determine the mean force for a desired swing (or time) interval.

[0026] Measurement and monitoring systems often present a user with a variety of measurements that quantify the athlete’s movement. While the measurements are meant to assist a golfer, too many measurements may have the opposite effect, i.e., confusing the golfer. To minimize the confusion to the golfer and to assist them with a quantitative measurement of their athletic motion, the present invention preferably mea-
ures the dynamic motion of the golfer and determines a single value that represents the ground reaction forces exerted by the golfer. The single value may be, for example, an impulse force, which is determined by integrating the resultant force over time. Preferably, the total impulse force may be calculated by using the measured force components (ground reaction forces) of the golfer. While this may be done in a variety of manners, preferably the impulse force is determined by integrating the measured force components over a predetermined period of time. The predetermined period of time may be, for example, the total swing time.

[0027] It is also desirable to compute the resultant moment about the vertical axis, e.g., the z-axis, using the z components of the moment for each foot. In addition, the mean torque may also be determined over one or more predetermined periods of time. These periods may be, for example, the time from initial take away of the club until impact with the golf ball, and the time from the start of the downswing until impact with the golf ball. Of course, other time periods may be used as desired. The torque, e.g., measured in Newton meters, may be useful for a variety of reasons. Since the torque is measured over various desired time periods, the duration of the application of the torque can also be measured. In addition, the duration of the torque application, as a percentage of the time period, may be calculated. By examining this data over several swings, a player may change the mechanics of his/her swing in order to increase the duration of the application of torque.

[0028] As mentioned above, each of the ground reaction forces are measured as a function of time. According to one aspect of the present invention, the force components may be used to compute different kinematic measurements in order to characterize the movement of the player. These measurements may include, but are not limited to, average force, average torque, impulse force, and angular impulse. The angular impulse may also be measured over predetermined time periods. In one embodiment, the time periods are the same as described above with respect to the torque and resultant force. Skilled artisans may calculate the angular impulse in a variety of manners. One way of calculating the angular impulse is to integrate the moment over the predetermined time period. Skilled artisans will recognize that it may be desirable to calculate other measurements, e.g., forces, moments, and impulses, over other intervals, when the present invention is implemented in combination with other sports or athletic motions.

[0029] At substantially the same time that the ground reaction forces are being measured, the dynamic characteristics of the golf club and golf ball may be also being determined. Preferably, the dynamic characteristics of the golf club and golf ball may be determined using a launch monitor. Typically, launch monitors include a variety of equipment including, but not limited to, a camera, a trigger, filters, illumination devices, displays, input devices, mirrors, processors, memory, and the like. To assist in obtaining images of the golf club and/or golf ball, launch monitors may be used in combination with markers that are placed on the golf equipment. Any type of markers may be used in combination with the present invention, including retro-reflective markers and limited spectrum markers, e.g., fluorescent markers.

[0030] In one embodiment, the launch monitor may measure dynamic characteristics of the club that include, but are not limited to, club head velocity, club head momentum, club head path angle, club head attack angle, club head loft, club head droop, club head face angle, club head face spin, club head droop spin, club head loft spin, and ball impact location on the club head face. Dynamic characteristics of the ball that may be measured include, but are not limited to, ball back spin, ball side spin, ball trajectory, ball speed, ball elevation angle, ball azimuth angle, ball rifle spin, and ball impact location on the golf club face.

[0031] Any type of launch monitor known to those skilled in the art may be used. Examples of launch monitors and launch monitor components that may be used include, but are not limited to, those disclosed in U.S. patent application Ser. Nos. 10/861,443, 10/656,882, and 10/667,479, and U.S. Pat. Nos. 5,471,383, 5,501,463, 6,758,759, 6,561,917, and 7,086,954, the entireties of which are incorporated herein by reference.

[0032] In one aspect of the present invention, the swing efficiency for a golfer using a particular club may be determined. This may be determined by plotting the total impulse force transmitted through the golfer’s feet versus the measured club head momentum. As mentioned above, the impulse force may be determined by integrating the forces exerted by the golfer over the predetermined period of time, e.g., the swing time. The impulse force correlates to the golfer’s weight shift from the back foot to the front foot. A golfer that has a lower impulse force exerts smaller forces over a certain time period and therefore expends less energy. Conversely, a golfer that has a higher impulse force exerts greater forces during his/her swing and therefore expends more energy.

[0033] The present invention may also determine the angular impulse of the golfer. The angular impulse may be determined by integrating the moment (torque) over the predetermined period of time, e.g., the swing time. The angular impulse correlates to the golfer’s turning motion about a central axis that passes through his/her body. A golfer that has a lower angular impulse exerts smaller torques and expends less energy. The opposite is also true, i.e., a golfer that has a higher angular impulse exerts more energy and exerts greater torques during his/her swing.

[0034] Both the impulse force and the angular impulse may be correlated with the measured club head momentum in order to determine the efficiency of the player’s golf swing. A golfer that expends a small amount of energy, i.e., has a low impulse force that results in a high club head momentum, is very efficient because they do a small amount of work to generate a high club head speed. Thus, in one embodiment, this may be quantified by calculating an efficiency ratio. The efficiency ratio may be calculated by dividing either the impulse force or the angular impulse by the momentum of the golf club. The highest efficiency is achieved by a player having the highest momentum and lowest impulse. In other words, the lower the efficiency ratio, the more efficient a golfer is.

[0035] The efficiency ratio may be used for a variety of applications. For instance, the efficiency ratio may be used to fit golf clubs to a particular golfer. Thus, a player may use several clubs and have his/her efficiency measured for a swing with each club. The efficiency ratios may then be compared to recommend a golf club to a golfer. Generally, the golf club with which the golfer achieves the lowest efficiency ratio would be the most desirable.

[0036] In addition to determining the efficiency of each golfer, the measured forces may be used to identify other characteristics of a golfer. For instance, the measured force over the predetermined period of time, e.g., the swing time, may be used to calculate the average force of a golfer. In a similar manner, the average torque may also be measured over the predetermined period of time in order to determine
the average torque. When implemented in combination with the sport of golf, these measurements provide several advantages.

[0037] For example, a player may experiment with various technique changes to determine which technique modifications improve their efficiency. In other embodiments, the present invention may be used to provide a fitness assessment for a player. In such an embodiment, the golfer may periodically conduct a measurement of their golf swing using the present invention to determine the effectiveness of various exercise routines. If, for example, their efficiency and/or average force or torque improves after implementing a particular exercise routine, they know to continue using that routine. Alternatively, if no improvement is made, the golfer will know to alter the routine. Examples of method and/or apparatus that may be used to assist a golfer in improving their fitness are disclosed in U.S. patent application Ser. Nos. 11/524,304, 11/364,343, and 11/228,349, the entireties of which are incorporated herein by reference.

[0038] As mentioned above, the present invention may be used to analyze the body movement of an athlete in any sport. These sports include, but are not limited to, baseball, soccer, football, tennis, hockey, basketball, racquetball, and the like. In these embodiments, the markers described above may be placed on the particular piece of equipment being utilized by the athlete. In some of these sports, such as football, it may be desirable to monitor the kinematic motion of both the ball that is thrown, as well as the athlete’s body part, e.g., his/her hand. In such an embodiment, the present invention monitors the kinematic motion of the player’s hand. This may be accomplished by placing markers on the body part being monitored. Alternately, infrared (IR) markers may be placed on the athlete’s body part. One example of a IR system for kinematic analysis that may be used in combination with the present invention is described in U.S. patent application Ser. No. 11/364,343, entitled “IR System for Kinematic Analysis,” the entirety of which is incorporated herein by reference.

EXAMPLES

[0039] Examples of the implementation of the present invention follow. Three golfers, A, B, and C, may be used to explain one aspect of the implementation of the present invention. As mentioned above, various kinematic measurements of both the golfer and the equipment may be determined by the present invention. The measurements for players (golfers) A, B, and C are shown in FIGS. 1-4. Specifically, FIGS. 1 and 2 show the kinematic measurements for each player from the initial take-away of the club to impact. FIGS. 3 and 4 show the kinematic measurements for each player from the start of the downswing to impact. For each of these portions of the club swing, the mean torque, angular impulse, duration of the torque application, and duration of the torque application as a percentage of that portion of the swing are determined. FIG. 5 shows the club head velocity as measured by a launch monitor and also the momentum of the club head.

[0040] The mean torque for players A, B, and C from the initial take-away of the club to impact is shown in FIG. 1. Player A has the lowest torque, player C has the highest torque, and player B’s torque is in between the torque of players A and C. Thus, player C uses the most force to rotate his/her body about a central axis, and player A uses the least force to rotate his/her body, while player B’s rotating force is in between player’s A and C. The mean torque provides a quantitative measurement of the strength and/or flexibility of the muscles used by each player to generate a turning motion about a vertical axis, e.g., their hip and abdominal muscles.

[0041] The mean force, which correlates to a player’s strength, e.g., their arm, shoulder and leg strength is shown in FIG. 2. In this case, player A has the lowest mean force, player B has the highest mean force, and player C has a mean force in between player’s A and B. Taken alone, this information indicates that player A is the weakest, player B is the strongest, and player C’s strength is in between players A and B. This information can also be combined with the mean torque measurements to provide valuable information. In particular, while player B appears to be the strongest, his rotating forces are not particularly strong. This data indicates that player B may be overcompensating for his lack of torque with excessive upper body strength and/or movement. A golf professional may analyze this information to determine how to instruct player B to correct his/her body movement. Similar information may be gleaned from an analysis of the mean force and torque in FIGS. 3 and 4.

[0042] This is just one example of the manner in which the kinematic measurements in FIGS. 1-4 may be used to analyze a player’s movement. The angular impulse, i.e., the integral of the torque over the swing time, and the impulse force, i.e., the integral of the force over the swing time, may be used in a similar manner to analyze a player’s body movement.

[0043] The present invention may also be used to quantify a golfer’s swing in terms of strength and efficiency of momentum transfer. For instance, in one embodiment the present invention determines an efficiency ratio, which is determined by dividing the angular impulse or impulse force by the momentum of the golf club. As explained above, a player with a smaller efficiency ratio achieves a better transfer of momentum to the golf club head during the swing. Using the efficiency ratio, a skilled artisan may use the present invention to isolate highly efficient golfers. FIG. 6 is a table showing the efficiency ratios for players A, B, and C. As shown in FIG. 6, player A’s efficiency ratio is the lowest at 7.1, followed by player C’s ratio of 12.6, and finally player B is the least efficient with a ratio of 18.5. The efficiency ratio may be used to analyze each golfer’s swing, as described below.

[0044] FIGS. 7-12 are graphical representations of the data shown in FIGS. 1-4. FIG. 7 is a chart showing player A’s impulse force, measured in Newtons (N), plotted versus the time of the swing. FIG. 8 is a chart showing the angular impulse, measured in Newton-meters (N-m), plotted versus the time of the swing, also for player A. FIGS. 9 and 10 show similar data for player B, respectively, and FIGS. 11 and 12 show similar data for player C, respectively. Each of the figures indicate which part of the graphs correlate to the backswing, downswing, and follow through for each player.

[0045] The data shown in the graphs represents each individual swing ‘signature’ and reveal some fundamental commonalities among all three players. To begin with, a large spike in the force data near the time of impact is present in all three force profiles. The force spike is caused by each golfer shifting their weight laterally during their swing, from the back foot to the front foot. In addition, a general reversal of polarity in the resultant torque near the time of impact occurs in all three moment profiles. A large positive torque build up is associated with the backswing. This torque is released during the downswing, creating an equilibrium condition just before impact. After impact, as the body starts to ‘follow through’ and wrap around, causing a large negative, i.e., opposite direction, torque is created. The duration of the torque application and the duration of the torque application as a percentage of the swing is shown in FIGS. 1 and 4. In particular, FIG. 1 shows the torque measurements from initial take-away to impact and FIG. 4 shows the torque measurements from the start of the downswing to impact.
A skilled artisan presented with these graphs can readily identify that player A has the highest swing speed and is the most efficient (based on the efficiency ratio) at transferring momentum to the golf club head. Player A also has the lowest torque values, and the lowest force values. In addition, player A applies the torque for the longest percentage of time up until impact, and ultimately transfers the largest amount of momentum to the golf club head. Player B (FIGS. 9 and 10) has the second highest club head speed. While player B’s torque values are similar to player A’s, the torque is applied over a much shorter percentage of the backswing and downswing. Because player B generates the largest forces of all three players, it is a strong indication that he/she is the strongest. As such, the data indicates that player B has a relatively high swing speed due to his/her sheer strength, but he/she is the least efficient at transferring momentum to the club head.

Player C (FIGS. 11 and 12) generates a moderate amount of force and torque relative to the other two players, indicating that he/she is neither the strongest nor the most efficient, and his/her club head velocity is the lowest.

Although the invention has been described with reference to particular embodiments, it will be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments within the spirit of the appended claims.

1. A method for comparing the dynamic characteristics of a golfer’s body with the dynamic characteristics of the golfer’s swing, comprising:
   - determining force components of the golfer’s body by measuring forces transmitted through each of the golfer’s feet during the golfer’s swing;
   - determining a resultant force based on the force components;
   - determining the club head velocity of a golf club swung by the golfer; and
   - comparing the resultant force with the club head velocity.

2. The method of claim 1, wherein the force components are measured as a function of time.

3. The method of claim 1, wherein the determining the resultant force comprises:
   - correcting the force components to account for a weight component of the golfer; and
   - combining the corrected force components to yield the resultant force.

4. The method of claim 1, wherein a club head momentum is determined using the club head velocity, the method further comprising determining an efficiency ratio based on the resultant force and the club head momentum.

5. The method of claim 4, further comprising using the force components to determine a resultant moment, as a function of time, about a vertical axis passing through the golfer’s body.

6. The method of claim 5, further comprising determining an angular impulse based on the resultant moment.

7. The method of claim 6, further comprising determining an angular momentum efficiency ratio based on the angular impulse and the club head momentum.

8. The method of claim 1, further comprising determining an average force and torque for at least one of the following two time durations:
   - a time from an initial club take away to an impact with a golf ball; and
   - a time from a start of a downswing until an impact with a golf ball.

9. A method for measuring the dynamic characteristics of an athlete’s performance, comprising:
   - determining force components transmitted through the athlete’s feet;
   - using the force components to determine a single value representative of the athlete’s performance;
   - determining the dynamic characteristics of a piece of athletic equipment manipulated by the athlete; and
   - comparing the single value representative of the athlete’s body movement with the dynamic characteristics of the piece of athletic equipment.

10. The method of claim 9, further comprising determining the moment of the athlete’s body about an axis and comparing it to the dynamic characteristics of the piece of athletic equipment.

11. The method of claim 9, further comprising determining the efficiency of the athlete’s body movement based on the single value representative of the athlete’s body movement and the dynamic characteristics of the piece of athletic equipment.

12. The method of claim 9, further comprising determining the dynamic characteristics of a body part of the athlete.

13. The method of claim 9, wherein the force components are measured as a function of time.

14. An apparatus for correlating the dynamic characteristics of a golfer’s body with the dynamic characteristics of the golfer’s swing of a golf club, comprising:
   - a force plate selectively positioned beneath the golfer’s feet;
   - a camera for acquiring one or more images of the golf club; and
   - a processor operatively connected to the force plate and the camera, wherein the processor is operable to compute a resultant force from the force plate and a golf club head velocity from the one or more images of the golf club.

15. The apparatus of claim 14, wherein the force plate is operable to measure force components of each of the golfer’s feet.

16. The apparatus of claim 14, wherein the resultant force is used to determine various stages of a golf swing including backswing, downswing, and follow through.

17. The apparatus of claim 14, wherein the processor is operable to compute the resultant force to the club head velocity.

18. The apparatus of claim 14, wherein the processor is operable to determine the moment of a golfer’s body about an axis.

19. The apparatus of claim 14, wherein the force plate comprises a first force plate and a second force plate, wherein the first force plate is selectively positioned under a first foot of the golfer, and the second force plate is selectively positioned under a second foot of the golfer.

20. The apparatus of claim 15, wherein the resultant force is a single value computed from the force components of each of the golfer’s feet.