Sex-based comparison of limb segmentation in ostriches aged 14 months with and without tibiotarsal rotation

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ABSTRACT

The aim of this study was to propose equations to predict changes that occur over time in the angular position of the bones during motion and the angular velocity of the bones in forward motion as a consequence of tibiotarsal rotation (TTR) in ostriches aged 14 months. Twenty-four normal 14-month-old ostriches (12 cocks and 12 hens) and 20 birds with TTR (9 cocks and 11 hens) were used in the study. Daily readings of temperature, relative humidity and rainfall, the lengths of the different segments of the legs and wings, the perpendicular height from the top of the torso to ground level and the length of the erect neck were recorded. Measurements of the degree of valgus deformity in the left foot were made where applicable. TTR hens and cocks were smaller in stature than normal birds. Comparing TTR hens and cocks, the toe, claw, humerus, perpendicular height and angle of rotation were larger in cocks, indicating a larger body in cocks. Hens were more severely affected by TTR. We suggest that the equations used in this study will assist in measuring movement of ostriches and how movement is compromised by overcrowding and TTR. Birds suffering from TTR may experience an increased degree of stress due to movement restrictions in confinement.

Key words: extension, equation, gait, ostrich, stress, tibiotarsal rotation.

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INTRODUCTION

The differences in movement between normal ostriches and ostriches with tibiotarsal rotation (TTR) of both sexes aged 14 months and destined for slaughter were investigated. The reason for this research is that the efficiency of movement of birds as well as their stress levels during the period when they are age-matched and isolated in groups of up to 55 in paddocks before slaughter at an on-farm abattoir[2,3] have an ultimate bearing on meat quality. TTR has been widely reported in ostriches up to 6 months of age[1,10], and recently in ostriches aged 14 months[7].

The aim of the current study was to propose an equation to determine gait (speed, kicking force and extension) in normal ostriches and ostriches with tibiotarsal rotation (TTR) aged 14 months. Leg and wing segments were compared in aged-matched birds either suffering from TTR or not. This study forms an extension of previous work[7]. Body measurements were taken and unique and novel equations proposed to predict gait and movement of normal and TTR ostriches at 14 months of age.

MATERIALS AND METHODS

A 21 ha ostrich farm in Poland (Ferma Strusi Stypułów, 67–120 Kożuchów; 51°43′N and 15°33′E) was selected for this study. The farm was laid out in paddocks for chicks (3, 6 and 8 months old), growers (9–12 months old) and breeders (>12 months old). Twenty-four normal ostriches (12 cocks and 12 hens), and 20 birds with TTR (9 cocks and 11 hens) aged 14 months were selected for the study. Each birds was identified by a tag. All the birds were allowed to roam freely in paddocks (8 × 50 m) that contained both the running and feeding areas. Paddocks on this farm were designed to hold a maximum of 25 birds before slaughter. Birds were therefore housed by numbers in separate paddocks without separation of sexes. The birds were granted *ad libitum* access in the feed room to feed that consisted of fresh, chopped lucerne and feed mix (14.5 % protein; 9.5 MJ/kg), consumed at 1.5 kg/day/bird, and water.

Twenty-four-hourly readings of temperature, relative humidity and rainfall were obtained using a portable weather station (IT Works KW9007-U, Comet, Birmingham, UK).

In order to measure the birds, they were isolated, hooded, weighed and directed into their feed room (30 m^2). A 50 m tape-measure was used to determine the segment lengths of the legs (femur, tibiotarsus/fibula/tarsometatarsus, phalanx I, digit III, toe (phalanx II, digit III, phalanx III, digit III and phalanx IV, digit III) and claw), wings (humerus, ulna/radius and manus (carpometacarpus, alular digit and main digit)), the perpendicular height from the top of the torso to ground level and the length of the erect neck.

Equations were derived based on the assumption that the average body weight of a normal cock was 120 kg. We considered that the movement within the paddock was restricted compared with that observed in the wild. We assumed therefore that the movement of the femur and fibula association was minimal. We determined, using principles of radial motion[9], the proposed movement of bones particular to TTR including tibiotarsus/fibula; tarsometatarsus/hypotarsus; and phalanx I, digit III and associated foot bones. These equations were theoretically derived and were not used to determine parameters. The derivation of the equation for angular movement of the limb bones was based on a pivot point movement about a joint, where R is the length of the bone in cm and θ is the determinant angle within the joint as the bones move. We proposed the radial position vector of relative bone position as $\hat{e}_R$. The transverse radial component represented the change in angle θ described by $\hat{e}_\theta$. The angular position vector represented by $\bar{e}$ described the motion of R in terms of $\hat{e}_R$. Velocity ($\bar{v}$) was defined as the change of the position vector over change in time (t)

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for the motion (Fig. 1).

Measurements of the degree of valgus deformity (Fig. 2) in the left foot were made where applicable. This was conducted by protraction from the normal direction of the toe at right angles and the angle of deviation determined. Values were presented as mean ± SD (Table 1). Statistical comparisons were performed using ANOVA (Minitab Inc., Philadelphia, USA) to determine differences in measurements between normal cocks and hens, and to determine differences between normal and TTR birds. A 2 × 2 factorial design included the following factors: sex (cock *vs* hen) and condition (TTR *vs* unaffected). $P < 0.05$ was taken as significant.

RESULTS AND DISCUSSION

The 24-hr temperature recordings inside feeding houses and outside in the paddock was 20.40 (mean) ± 0.12 (SEM) °C and 14.98 ± 1.35 °C, respectively, and exterior relative humidity 50.00 ± 0.67 %. Rainfall averaged 4 mm. No extreme weather was observed. These values were regarded as normal and within acceptable limits for ostrich rearing[4].

The farmer informed us that the annual incidence of leg deformities was approximately 8–10 %, occurring principally in the left foot. The frequency of TTR in the cohort under study was 22.6 %, with 0.3 % incidence of TTR in the right foot.

The body weight determination in normal and TTR cocks was 120 ± 1 kg and 115 ± 1 kg, respectively. The hens' body weight was 116 ± 1 kg (normal) *vs* 114 ± 1 kg (TTR). The difference in weight emphasises the degree of degeneration of musculature in TTR birds and the resultant loss of revenue from meat and skin sales. TTR hens and cocks were smaller in stature than normal birds (Table 1). Overall, from data presented in Table 1, there were no significant differences in parameters between normal hens and cocks, unlike those determined between TTR hens and cocks. However, given the scarcity of data on limb and associated locomotion parameters in ostriches, we felt it was essential to include data on all aspects of segment measurements.

The lack of dimorphism between normal hens and cocks is in agreement with previous investigations[1,6,8]. The birds become stunted as a consequence of the TTR condition. The only significantly ($P < 0.05$) larger difference in measurements between normal hens and cocks was phalanx I, digit III, which was elevated in cocks (Table 1). Statistical evaluations between TTR hens and cocks revealed that toe, claw, humerus, perpendicular height and angle of rotation were significantly ($P < 0.05$) higher in cocks (Table 1). Larger humeri would aid kantling behaviour in cocks. The degree of rotation in the left foot was severe and suggested a progressive pathological condition associated with age[5]. Cooper[7] deduced that this attenuates the stride length and running speed in TTR birds. This aspect of TTR in hens was well demonstrated, as most parameters were attenuated (femur, tibiotarsus/fibula/tarsometatarsus, toe, humerus, ulna/radius and perpendicular height) and elevated (phalanx I, digit III; and neck) in the TTR hens in comparison with normal hens (Table 1), suggesting that limb movement and balance afforded by wings are compromised. Cooper[7] demonstrated that normal hens aged 14 months are able to outrun cocks over a distance of up to 20 m, implying that TTR does result in disadvantaged movement. The observations suggested that TTR in cocks may adversely affect their patrolling behaviour. In TTR cocks the femur, tibiotarsus/fibula/tarsometatarsus, toe, humerus, ulna/radius and perpendicular height were significantly ($P < 0.05$) lower compared with normal cocks (Table 1). However, the phalanx I, digit III was significantly ($P < 0.05$) higher in cocks (Table 1). Previous studies suggest genetics, management, sex, nutrition and growth rates as important contributors to TTR[5,6]. However, a complete understanding of

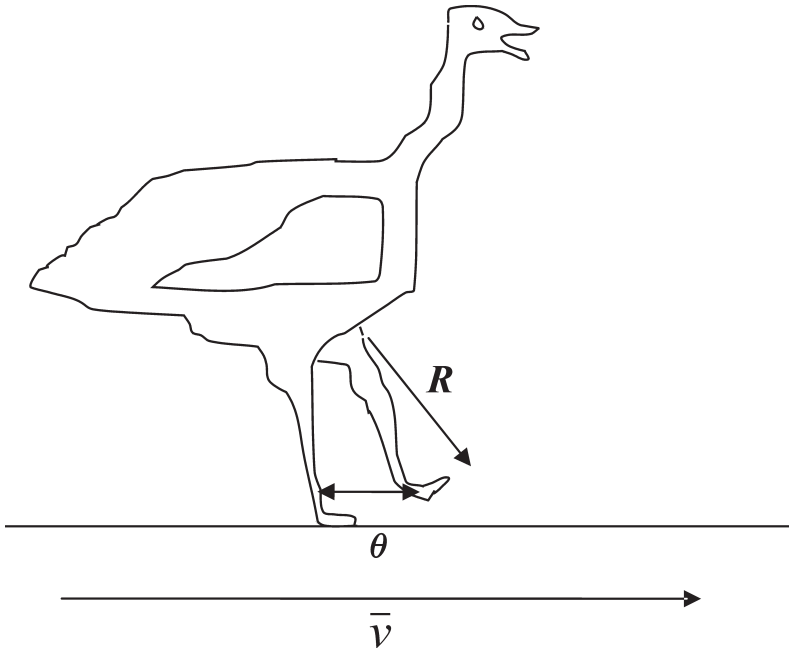

Fig.1: **Motion dynamics in the ostrich described as a velocity ($\bar{v}$) change of the position vector over change in time (t) with θ representing the determinant angle within the joint as the bones move.**

Fig. 2. **Tibio-tarsal rotation in the left limb expressed as an outward deviation from normal toe position.**

Table 1. **Sex-based comparison of segment measurements** (mean ± SD) **of legs and wings, and perpendicular height, neck and angle of rotation in normal and TTR 14 month old ostriches.**

Index (cm)	Normal hen	Normal cock	TTR hen	TTR cock
Femur	63.33 ± 2.65	65.00 ± 2.41	50.86 ± 2.96†	56.14 ± 2.84‡
Tibiotarsus/fibula/tarsometatarsus	44.92 ± 2.28	44.58 ± 2.07	40.71 ± 2.69†	39.86 ± 2.10‡
Phalanx I, digit III	7.17 ± 1.03	8.83 ± 1.21*	9.64 ± 0.75†	10.64 ± 2.14‡
Toe (phalanx II, digit III, phalanx III, digit III and phalanx IV, digit III)	13.58 ± 1.13	14.33 ± 0.39	8.14 ± 1.41†	10.07 ± 1.34§‡
Claw	4.50 ± 0.48	5.21 ± 0.50	4.93 ± 1.10	5.64 ± 0.56§
Humerus	33.50 ± 1.68	32.50 ± 1.57	25.64 ± 1.98†	26.00 ± 1.77‡
Ulna/radius	25.96 ± 1.22	23.33 ± 1.45	18.71 ± 2.08†	18.71 ± 1.63‡
Manus (carpometacarpus, alular digit and main digit)	14.58 ± 0.60	15.13 ± 1.05	13.93 ± 2.52	14.00 ± 1.99
Perpendicular height	135.42 ± 3.12	134.08 ± 2.61	125.00 ± 2.12†	128.14 ± 2.46§‡
Neck	84.58 ± 1.99	85.67 ± 1.61	87.29 ± 1.93†	88.43 ± 2.38
Angle rotation in left foot (°)	–	–	65.29 ± 2.77	70.86 ± 1.54§

*P < 0.05 normal hen *vs* normal cock; $^{\S}P$ < 0.05 TTR hen *vs* TTR cock; $^{\dagger}P$ < 0.05 normal hen *vs* TTR hen; $^{\ddagger}P$ < 0.05 normal cock *vs* TTR cock.

TTR is lacking and requires much more scientific investigation.

Equation (1) describing the change in angular position of the bone during motion was:

$$\bar{e} = R\hat{e}_R, \quad (1)$$

where $\hat{e}_R = \cos\theta\hat{i} + \sin\theta\hat{j}$ and $\hat{i}$ and $\hat{j}$ represent x and y components of the vector, respectively.

Equation (2) describing the angular velocity of the bone in forward motion in time (t) at a joint was:

$$\bar{v} = \frac{dR}{dt}\hat{e}_R + \frac{d\theta}{dt}\mathrm{R}\,\hat{e}_\theta\,, \quad (2)$$

where $\hat{e}_\theta = \cos\theta\hat{i} + \sin\theta\hat{j}$ and $\hat{i}$ and $\hat{j}$ represent x and y components of the vector, respectively.

It is suggested that these equations will assist in determining various aspects of movement of ostriches, including those affected by TTR. We recognise that these equations are unique and recommend a thorough collection of limb and gait data from ostriches of known age destined for slaughter. One would have to determine values for R and θ. This would form a useful extension to the studies by Paul[11] and Rubenson *et al.*[12] to assess how the limbs of ostriches evolved to produce their unique gait and locomotion. Birds suffering from TTR may experience an increased degree of stress due to movement restrictions in confinement. Mathematical equations to describe the movement of large flightless birds are unquestionably essential in making ecological comparisons between the ostrich and other ratites, both living and extinct. It is hoped that adding to the knowledge of limb morphology and locomotion dynamics we contributed to preventing further threats to and indeed extinctions of ratite species.

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