INFLUENCE OF SEX ON GROWTH PERFORMANCE, CARCASS ATTRIBUTES, MEAT QUALITY, AND BLOOD METABOLITES OF AWASSI LAMBS

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ABSTRACT

This study evaluated the effect of sex on growth performance, carcass characteristics, meat quality, and blood metabolite parameters of Awassi lambs. Twenty-seven Awassi lambs were allocated into two sex groups: males (n=13) and females (n=14). Lambs were individually penned and fed according to the nutritional needs of small ruminants. The experimental period of the study continued for 63 days, preceded by seven days for dietary and pen adaptation. On day 56 of the experimental period, five lambs of each sex group were randomly chosen and distributed in metabolism chambers to examine the digestibility and nitrogen balance. After 70 days of the trial, all lambs were butchered to determine their carcasses and meat quality. The average dry matter (DM) and crude protein (CP) intakes were significantly affected by sex ($p < 0.05$). Both sexes had similar DM and CP digestibility. Male lambs had greater nitrogen intake and retention ($p < 0.05$). Growth performance, weights of fasting animals, weights of hot and cold carcasses, non-carcass parts and carcass cuts were influenced ($p < 0.05$) by the lambs' sex.

Keywords: male lambs, female lambs, digestibility, nitrogen balance

تأثير الجنس في أداء النمو وصفات الذبيحة ونوعية اللحوم ومتأيضات الدم للحملان العواسي

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المستخلص

أجريت هذه الدراسة لتقييم تأثير الجنس على أداء النمو، خصائص الذبيحة، جودة اللحوم ومعامل أيض الدم في الحملان العواسي. تم تقسيم سبعة وعشرون حملاً عواسيًا إلى مجموعتين جنسيتين: الذكور (n = 13) والإناث (n = 14). تم وضع الحملان بشكل فردي وتغذيتها وفقًا للاحتياجات الغذائية للحيوانات المجترة الصغيرة. استمرت الفترة التجريبية للدراسة لمدة 63 يومًا، سبقها 7 أيام تمهيدية للتأقلم الغذائي والمكاني. في اليوم 56 من الفترة التجريبية، تم اختيار 5 حملان من كل مجموعة جنسية عشوائيا وتوزيعها على غرف الاستقلاب لفحص قابلية الهضم وتوازن النتروجين. وبعد 70 يومًا من التجربة، تم ذبح جميع الحملان لتحديد جودة ذبائحها ولحومها. تأثر متوسط تناول المادة الجافة والبروتين الخام بشكل كبير بجنس الحملان (P <0.05). كانت قابلية هضم المادة الجافة والبروتين الخام مماثلة لدى كلا الجنسين. كان لدى الحملان الذكور كمية أكبر من النيتروجين والاحتفاظ به (P <0.05). تأثر أداء النمو وأوزان الحيوانات الصائمة وأوزان الذبائح الحارة والباردة واجزاء الذبيحة غير المأكولة وقطع الذبيحة (P <0.05) بجنس الحملان.

الكلمات المفتاحية: ذكور الحملان، إناث الحملان، الهضمية، توازن النيتروجين

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INTRODUCTION

In Jordan, the local Awassi sheep breed is the most predominant breed, which is raised for multiple purposes and is highly relevant to generating income, food security, and livelihoods of householders (16). Awassi breed is a prominent reservoir of genetic diversity compared to other breeds due to its high adaptability and tolerance to diverse environments (16, 24). It is found in over 30 countries of its origin (5, 25). In 2020, ovine meat production accounted for about 4.9% of the global meat production and increased by 0.9% compared to 2019 (14). In Jordan in 2020, sheep were the largest registered livestock population, numbering approximately 3,503,585 heads and producing about 15.372 tons of meat, constituting 42% of the total annual local production of red meats (30). However, in Jordan, the self-dependence percentage of red meat production is about 25%, and the per capita consumption of red meat in Jordan is around 8.5 kg (30), which is insufficient to meet the needs. Consequently, the red meats of other livestock species are imported from other foreign countries, especially during religious festivals where the highest percentage of slaughtering occurs (30). In Jordan, there is a growing need and preference for consuming Awassi lamb meats, which have better meat quality attributes (44) than other red meat types. However, the slaughtering and purchasing decisions of consumers for Awassi meat type depend, in most cases, on the sex of the animal. Genetic, environmental, and physiological factors can influence sheep carcasses and meat quality characteristics (4, 22, 29, 39, 49). Moreover, carcass tissue maturation and distribution are essential for meat production and assessing carcass quality (6). Meat quality attributes include palatability (tenderness, juiciness, and flavor), water-holding capacity (WHC), color, and nutritional value, and they can be affected by genetics, production, and processing factors (20). Consumers' purchasing decisions for certain meat types depend mainly on meat quality cues such as meat origin, safety, price, production system, and quality (3). In the classification system, carcass weight, fat amount, sex, age, and percentage of commercial cut are important traits in grouping lamb carcasses into commercial grades (1). The previous kinds of literature that have been conducted on the Awassi breed in Jordan focused mainly on the effects of diet, breed, and genetics on growth performance, carcass characteristics, and meat quality (1, 2, 7, 8, 21, 23, 32, 33, 34, 35) However, these studies and others did not consider sex as the main effect. Thus, there is a shortage of information on the impact of sex on growth performance, carcass characteristics and meat quality, and blood metabolite parameters of growing Awassi lambs. The present study was conducted to enhance knowledge in this context. It was assumed that carcass characteristics, meat quality, and blood metabolite parameters could be varied by lamb sex. Therefore, this research aimed to assess the effect of sex on growth performance, carcass characteristics and meat quality, and blood metabolites parameters of growing Awassi lambs.

MATERIALS AND METHODS

Experimental animals and design

The study was conducted on 27 Awassi lambs (13 males and 14 females), with an average initial body weight of 16.1 + 0.23 kg and 70 days of age at the Research and Training Facility within the Faculty of Agriculture at the Jordan University of Science and Technology (JUST). Before beginning, the Animal Care and Use Committee (ACUC) in JUST accepted all procedures for handling animals in this research. Lambs were randomly selected and assigned in a completely randomized design (CRD) into two sex groups: male and female. Lambs were given a concentrate diet according to NRC (31) standards. This concentrate is composed of barley grain (50.5%), soybean meal (17.5), wheat straw (19%), alfalfa hay (11%), salt (1%), limestone (0.9%), and minerals and vitamins (0.1%). Composition per kilogram of the mineral and vitamin mix contained vitamin A, 600,000 IU; vitamin D3, 200,000 IU; vitamin E, 75 mg; vitamin K3, 200 mg; vitamin B1, 100 mg; vitamin B5, 500 mg; lysine 0.5 g/100g; DL-methionine, 0.15 g/kg; manganese oxide, 4000 mg; ferrous sulfate, 15,000 mg; zinc oxide, 7000; magnesium oxide, 4000 mg; potassium iodide, 80 mg; sodium selenite, 150 mg; copper sulfate, 100

mg; cobalt phosphate, 50 mg; dicalcium phosphate, 10,000 mg. The chemical composition of the concentrate was 91.8, 16.2, 31.4, 11.1, and 0.9% on a DM basis for DM, CP, neutral detergent fiber, acid detergent fiber, and ether extract, respectively. Lambs were individually separated and distributed in comfortable pens for 63 days, preceded by seven days for dietary and pen adaptation. On day 56 of trial period, 5 lambs of each sex group were randomly distributed in metabolism chambers to examine the digestibility and N balance. Three days of adaptation were given for lambs, and the collection of feces and urine took place over 4 days. Water and feed were presented for *Ad libitum*. Lambs' body weights were recorded at the onset of the study and biweekly before the morning meal. At the feeding trial's end, A ten ml of blood sample was withdrawn using jugular venipuncture of each lamb into an anticoagulated test tube using 5% EDTA. Serum samples were isolated by centrifugation at 3000 RPM for 30 minutes for blood constituents assay. Serum samples were transported and stored in the lab at 20°C until the day of the blood constituents testing as soon as they were separated. Serum glucose, urea N content, cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), triglycerides, creatinine, aspartate aminotransferase (AST), alkaline phosphatase (ALP), and alanine aminotransferase (ALT) were measured using a spectrophotometer and commercial kits in compliance with the manufacturer's instructions. After 70 days of the experiment, all lambs were humanely butchered to assess their carcasses and meat quality.

Slaughtering procedure

At the end of the experiment, lambs were abstained from feed and water for 18 h and slaughtered by trained staff at 9:00 a.m. at JUST's Center for Training and Research Unit facilities to assess carcass characteristics. All of the slaughtering processes of lambs applied in this study were detailed and reported in the previous study by Obeidat et al. (33). Instantly prior to slaughter, the weights of live fasted lambs were measured using a precision scale, and the hot carcass weights were determined shortly afterward. The cold weights of carcasses were recorded after keeping the carcasses at a temperature of 4°C for 24 hours. The dressing percentage was computed as (cold carcass weight/live fasting weight) *100 (15). Non-carcass organs, including the heart, kidney, liver, spleen, lungs, and trachea, were removed, weighed, and recorded after slaughter. One day post-mortem, the cooled carcasses were portioned into four commercial sections, as reported by Obeidat et al. (33): loin, rack, leg, and shoulder. Afterward, the linear dimensions of the following measurements: depths of leg fat (L3), tissue (GR), rib fat (J), eye muscle (B), fat (C), and width of eye muscle (A) were determined using a meat caliper. Then, the *longissimus dorsi* muscle was excised from the loin cut and stored vacuum-packed at -20°C in an ultra-low lab freezer for a 14-day until the stipulated time for the assessment of meat quality measurements.

Meat quality measurements

Water holding capacity (WHC), cooking loss (CL), shear force (SF), pH, and color parameters (CIE L*, a*, b*) were all assessed as clarified by Obeidat et al. (33). While left closed in plastic bags, the frozen *longissimus dorsi* muscles were melted for the duration of a night in a refrigerator at 4°C. Muscles were divided into segments of differing thickness, and he meat quality of each segment was evaluated using different test. Color was detected in 15-mm-thick segments and it was measured at three different marks of the cut using the CIE system which reflects the color indices; lightness (L*), redness (a*), yellowness (b*), using a colorimeter (12MM Aperture U 59730-30, Cole-Parameter International, Accuracy Microsensors Inc., Pittsford, NY, USA). All segments were put on a polystyrene tray, covered with a hole-ridden film, and oxygenated for two hours at 4°C. CL was assessed using 25-mm-thick segments of meat. Before cooking, the segments' weights were recorded; after that, the segments were put in plastic bags, then heated in a water bath at 75°C for 90 minutes employing the sous vide cooking method (9), and weighed again after cooking. Afterwards, CL percentage was calculated as weight difference: [(initial weight – final weight)/ initial weight] *100. To obtain SF values, the

cooked segments were cooled at 4°C for a night before being divided into six reduced samples of 1 cm^3 each. Furthermore, to identify the maximum force (kg) needed to shear cooked meat cores, samples were positioned in a Salter Model 235, provided with a Warner-Bratzler (WB) shear blade, with a triangular slot sharp end (Warner-Bratzler meat shear, GR Manufacturing Co., Manhattan, Kansas, USA). WHC was determined by using the Grau and Hamm's (17) method. The pH value of the meat was recorded through a electronic pH meter. A sample of 5 g of raw meat were divided into small portions and put between two filter papers and two quartz plates, then smashed with a 2.5 kg weight for 5 min, and ultimately obtained and weighed once more. The WHC percentage was calculated as a weight difference using this equation = [(initial weight – final weight)/initial weight] * 100.

Statistical analysis

A completely randomized design (CRD) was used as an experimental design. The whole data set was examined using SAS' MIXED procedures (Version 8.1, 2000, SAS Inst. Inc., Cary, NC), with the sex serving as the explanatory variable. Lambs was utilized as a random variable. For slaughter measurements, carcass weight was considered as a covariate in statistical analysis for error control. The LSM has been separated using the relevant pair-wise t-tests if the independent (explanatory) variable were considerable ($P \leq 0.05$).

Table 1. Effects of sex on nutrient intakes, digestibility, and N balance of Awassi lambs

Item	Sex		SEM	P-value
	Male (n = 13)	Female (n = 14)		
Dry matter intake (g/d)	1169[a]	1044[b]	18.8	< 0.0001
Crude protein intake (g/d DM)	187[a]	167[b]	3.0	< 0.0001
Dry matter digestibility (%)	79.8	77.7	1.12	0.2503
Crude protein digestibility (%)	81.4	78.6	1.76	0.2930
Nitrogen balance				
N intake (g/d)	29.4[a]	27.1[b]	0.40	0.0143
N lost in feces (g/d)	5.2	6.5	0.62	0.1761
N lost in urine (g/d)	7.4	7.3	0.91	0.9226
Retained N (g/d)	16.8[a]	13.3[b]	0.73	0.0277
Retention (%)	56.9[a]	49.0[b]	1.77	0.0337

SEM: Standard error of mean,
Means with different superscripts within each row differ significantly ($P \leq 0.05$).

RESULTS AND DISCUSSION

Nutrient intakes, digestibility and N balance

In this study, the effect of sex on DM and CP intakes was evident ($p < 0.05$), with males having a higher DM and CP intakes (Table 1). This observation is in line with research findings reported by Pereira et al. (38) and de Araújo et al. (12) who reported higher DM intake in intact and castrated hair and Morada Nova lamb males than females, respectively. This result is also in agreement with those by Hanim and Muhlisin (18) who indicated higher DM and CP intakes in male Merino than female one, by Canton-Castillo et al. (10) who observed a higher DM intake of male lambs than females, by Pal et al. (36) in which nutrient intakes were higher in male than female calves. However, Rodríguez et al. (40) stated that feed ingestion of Assaf fattening lambs was not significantly affected by sex. The higher DM and CP intakes in lamb males in our study could be ascribed to an increase in the gain of their body weights because of anabolic impact of testosterone hormone, which require more nutrient intake to meet that increase in body weights. Interestingly, DM and CP digestibility in this study were comparable between two sexes (Table 1). Similarly, a study by Pal et al. (36) also revealed that the sex of the animal did not have any significant effect on nutrient utilization. In the contrary, Hanim and Muhlisin (18) reported that males of Merino sheep had higher value of DM intake and CP digestibility. In the present study, N utilization was different between sexes, as N intake and retention were significantly higher for male lambs than female ones ($p < 0.05$), while N excretion was not affected by sex. This discrepancy could be owing to higher DM and

CP intakes in male lambs and numerically improvement in digestibility of CP. However, a study by Zhao et al. (50) indicated that the N utilization efficiency in lowland lambs was unaffected by sex of lamb.

Growth performance

A significant impact of sex on lamb performance were observed (Table 2). The initial body weights of both sexes were comparable and increased considerably with advancing age of lambs. Nonetheless, the final male lambs' body weights were substantially higher ($p < 0.05$) than their female counterparts (31.3 vs. 27.6). Moreover, average daily gain (ADG) and total weight gain (TWG) were significantly higher for male lamb group than female lamb group (239 vs. 184) and (15.1 vs. 11.6), respectively. This outperforming can be explained by anabolic impact of testosterone hormone, which play a major role on body muscle building and fat makeup in the male (27). Greater weight gain values in males support the results presented by Kaya et al. (26) who also observed increased in final live weight and ADG in male Karayaka lambs, by Facciolongo et al. (13) who found higher daily growth rate in male Gentile di Puglia lambs than females, by de Araújo et al. (12) who reported higher ADG in intact and castrated Morada Nova lamb males than females, by Canton-Castillo et al. (10) who observed higher DWG in male Katahdin × Pelibuey lambs compared to females, by Vargas Junior et al. (46) who reported a greater males' production efficiency of local sheep and their crossbreds when contrasted with females. In contrast, ADG was not affected by sex of Moghani lambs (42).

Table 2. Effects of sex on growth performance of lambs

Item	Sex		SEM	P-value
	Male (n = 13)	Female (n = 14)		
Initial weight (kg)	16.2	16.0	0.23	0.4255
Final weight (kg)	31.3[a]	27.6[b]	0.52	0.0003
Total gain (kg)	15.1[a]	11.6[b]	0.53	0.0007
Average daily gain (g/d)	239[a]	184[b]	8.30	0.0006

SEM: standard error of mean,

Means with different superscripts within each row differ significantly ($P \leq 0.05$).

Carcass and non-carcass parts

The findings regarding the effects of sex on carcass and non-carcass parts of Awassi lambs are presented in Table 3. Male Awassi lambs presented higher ($p < 0.05$) fasting live weight, hot carcass weight, cold carcass weight, non-carcass organs (Heart, liver, spleen, kidney, and lungs and trachea) and carcass cuts (shoulder, racks, loins, and legs). However, sex did not affect dressing percentage and fat tail weight (Table 3). Male lambs exhibited heavier fasting live weights, hot and cold carcass weights in contrast to female lambs. In numerical terms, dressing percentage was higher for the males than for females. Higher dressing percentage in males than females could be explained by the heavier slaughter weights of males compared to females. Yateem et al. (48) found that an increase in slaughter weight was linked to an increase the dressing percentage. The current results are in line with those of Canton-Castillo et al. (10) who found greater hot carcass weights in males versus female lambs. Likewise, our findings were similar to work conducted by de Araújo et al. (12) who reported heavier hot and cold carcass weights in intact and castrated Morada Nova lamb males than females. In contrast, Klupsaite et al. (28), Sabbioni et al. (41) and Kaya et al. (26) reported similar hot and cold carcass weights between sexes in lambs. However, Sadeghi et al. (42) observed a significant greater hot carcass weight in males than female with comparable cold carcass weights and dressing percent. A study by Pena et al. (37) showed no significant effect of sex on hot carcass weight of segure˜na lambs. Moreover, sex had significant effects on non-carcass components and carcass cuts. Higher carcass cuts weights in males could be attributed to their heavier slaughter and carcass weights. This is in accordance with other studies (42) who found heavier non-carcass parts, carcass cuts and fat tails in males than in females, (12, 37) who stated significant impact of sex on non-carcass components.

Table 3. Effects of sex on carcass, and non-carcass components of Awassi lambs.

Item	Sex		SE	P-value
	Male (n = 13)	Female (n = 14)		
Fasting live (kg)	30.1[a]	26.4[b]	0.60	0.0010
Hot carcass (kg)	14.4[a]	12.0[b]	0.21	< 0.0001
Cold carcass (kg)	13.7[a]	11.8[b]	0.26	0.0002
Dressing percentage	45.6	44.6	0.85	0.4433
Non-carcass organs (kg)[1]	1.2[a]	1.1[b]	0.03	0.0068
Carcass cuts (kg)[2]	12.5[a]	11.0[b]	0.26	0.0017
Fat tail (kg)	797	688	122.5	0.2104

SE: standard error,
Means with different superscripts within each row differ significantly (P ≤ 0.05).
[1]Non-carcass components (Heart, liver, spleen, kidney, and lungs and trachea),
[2] Carcass cut (shoulder, racks, loins, and legs).

Table 4. Effects of sex on carcass linear dimensions of Awassi lambs.

Item	Sex		SE	P-value
	Male (n = 13)	Female (n = 14)		
Leg fat depth (*L3*) (mm)	1.69	1.21	0.256	0.2117
Tissue depth (*GR*) (mm)	7.54	6.14	0.460	0.0513
Rib fat depth (*J*) (mm)	1.65	1.21	0.275	0.2810
Eye muscle width (*A*) (mm)	47.04	47.57	1.031	0.7210
Eye muscle depth (*B*) (mm)	17.82	18.04	0.712	0.8127
Fat depth (*C*) (mm)	1.04	1.04	0.074	0.9591
Shoulder fat depth (*S2*) (mm)	1.00	1.04	0.026	0.3549

SE: standard error.

Carcass linear dimensions

Carcass leaner dimensions of both sexes for Awassi lambs are indicated in Table (4). In the current study, no significance differences in leg fat depth, the depth of rib fat, eye muscle's dimensions, fat depth and shoulder fat depth were recorded between two sex groups. However, tissue depth was marginally greater (p = 0.051) for male lambs. Regardless of sex, in the previous study (33) these linear measurements are particularly captured from the *longissimus dorsi* muscle and conducted to evaluate the carcasses regarding to tissue composition. Likewise, Van der Merwe et al. (45) reported that the fat and muscle tissue depths measured on *Longissimus lumborum* muscle were similar between the ram and ewe lambs of the various sheep breeds in South African.

Table 5. Effects of sex on meat quality characteristics of Awassi lambs.

Item	Sex		SE	P-value
	Male (n = 13)	Female (n = 14)		
pH[1]	5.65	5.73	0.053	0.3000
Cooking loss (g /100 g)	37.27	37.79	0.881	0.6358
Water holding capacity (g/ 100 g)	27.00	26.68	0.840	0.7352
Shear force (kg/cm^2)	8.39	8.25	0.370	0.7854
Color indicators				
L* (whiteness)	36.40	37.67	0.551	0.1310
a* (redness)	25.52	27.51	1.714	0.3834
b* (yellowness)	17.80	18.60	0.466	0.2488

SE: standard error,
[1] pH measured after thawing.

Meat quality characteristics

Awassi lambs' meat quality attributes of are shows in Table (5). Values of pH, CL, WHC, SF, and color coordinates (L*, a*, b*) were not affected by sex of lambs. The present results are in line with what Hassan et al. (19) revealed, that sex did not significantly affect the pH, color, drip loss, cooking loss and tenderness of Black goat and Meriz goat meats. With respect to the impact of sex on

meat quality characteristics, the meat pH values of the study were similar for both sexes and they were within appropriate range for meats. Similarly, a study by Vergara et al. (47) on Manchega Spanish breed showed that the sex did not affect pH and its drop after slaughter. The fresh meat color intensity or instability depends largely on its myoglobin concentration and its pH value (39). Since the pH values were similar between sexes, it is expected that color parameters of meat between two sexes did not differ. Due to the fat that there was no variance in muscle's cooking loss between both sexes, WHC and SF also remained unchanged between the sexes. However, a previous study showed that WHC was higher in male lambs than female lambs (47). Regardless of sex, the average values observed in our study for pH (5.69), CL (37.53), WHC (26.84), SF (8.32), L* (37.04), a* (26.52) and b* (18.2) were acceptable and comparable with values reported in the previous studies in Awassi lamb meat (7, 21) except for a* values, they were higher than those observed. The difference in redness values could be ascribed to discrepancies in diets, sex, slaughtering methods and carcass processing.

Blood parameters

The effect of sex on blood metabolites levels of Awassi lambs is detailed in Table (6). The two sex groups exhibited similarity in all serum metabolites, e.g. urea N, glucose, cholesterol, triglycerides, low density lipoprotein (LDL), high density lipoprotein (HDL), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP), creatinine. Diagnosis of blood serum metabolite concentrations is an essential method in the recognition of animal conditions, and intrinsic or extrinsic factors can influence them. In the present study, blood metabolites and liver enzymes were not affected by sex. Similarly, Santo da Cruz et al. (43) reported that the values of biochemical variables of Dorper lambs were not influenced by sex. However, other factors such as age, breed, and diet could significantly change these metabolite profiles (11). In conclusion, the study revealed that sex considerably impacted DM and CP intakes, N balance, growth performance, slaughter weights, carcass weights, non-carcass organs, and carcass cuts of growing Awassi lambs. On the other hand, sex did not significantly affect the digestibility of DM and CP, fecal and urinary N, meat quality characteristics, carcass linear dimensions, fat measurements, and serum metabolite concentrations. Therefore, the sex of the animal should be considered to produce a fattening animal to enhance returns from selling lambs or consumers purchasing animals to obtain good carcass quality for slaughtering.

Table 4. Effects of sex on blood parameters of Awassi lambs.

Item	Sex		SE	P-value
	Male (n = 13)	Female (n = 14)		
Urea N (mg/dL)	27.5	25.7	1.59	0.4413
Glucose (mg/dL)	79.7	78.9	5.48	0.9160
Cholesterol (mg/dL)	68.3	70.9	5.07	0.7285
Triglycerides (mg/dL)	27.0	25.3	5.22	0.8153
HDL (mg/dL) [1]	52.4	49.9	3.71	0.6313
LDL (mg/dL) [1]	13.1	13.4	2.61	0.9313
AST (IU/L) [1]	35.4	40.6	2.84	0.1282
ALT (IU/L) [1]	12.7	12.2	1.12	0.7670
ALP (IU/L) [1]	50.2	49.2	3.98	0.8595
Creatinine (mg/dL)	0.61	0.68	0.058	0.4129

SE: standard error,

[1] HDL: high-density lipoprotein, LDL: low-density lipoprotein, AST: aspartate aminotransferase, ALT: alanine aminotransferase, ALP: alkaline phosphatase.

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