Influence of age of horse on results of quantitative electromyographic needle examination of skeletal muscles in Dutch Warmblood horses

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Objective—To determine the influence of age on results of quantitative analysis of electromyographic (EMG) needle examination in the subclavian, triceps, and lateral vastus muscles of Dutch Warmblood horses.

Animals—7 healthy young Dutch Warmblood horses (range, 13 to 18 months old), 7 healthy adult Dutch Warmblood horses (range, 4 to 10 years old), and 7 healthy elderly Dutch Warmblood horses (range, 18 to 21 years old).

Procedure—An EMG needle examination was performed to evaluate insertional activity, spontaneous activity, and motor unit action potential (MUAP) variables. Although all horses were conscious, young horses were sedated prior to examination.

Results—Mean insertional activity in young horses was significantly lower than in elderly horses. Pathologic spontaneous activity was rarely found in young and adult horses but was frequently evident in all muscles in all elderly horses. The MUAP duration and amplitude were significantly lower in all muscles of young horses, compared with values for adult and elderly horses. The MUAP duration and number of phases and turns were significantly lower in adult horses than in elderly horses. Group differences for percentages of polyphasic and complex MUAPs were also found. The 95% confidence intervals for MUAP duration, MUAP amplitude, and number of phases and turns for the subclavian, triceps, and lateral vastus muscles were significantly lower in young horses than in adult or elderly horses.

Conclusions and Clinical Relevance—Age of the horse being examined should be considered when EMG examination is performed. (*Am J Vet Res* 2003;64:70–75)

Needle **electromyography (EMG)** is a neurophysiologic technique in humans that enables objective discrimination between neurogenic and myogenic disorders, localization of disorders, and determination of the optimal site from which to obtain a muscle biopsy.[1,2] The technique comprises systematic examination of muscles for insertional activity induced by needle placement, evidence of pathologic spontaneous activity as a result of spontaneously firing single muscle fibers, and quantitative analysis of **motor unit action potentials (MUAPs)**. In humans, detection of fibrillation potentials, positive sharp waves, complex repetitive discharges, and myotonic discharges in combination with short-duration, low-amplitude, polyphasic MUAPs indicates myopathy,[3-5] whereas detection of fibrillation potentials, positive sharp waves, neuromyotonia, and doublets, triplets, and multiplets in combination with long-duration, high-amplitude, polyphasic or complex MUAPs indicates neuropathy.[5,6] In humans, factors that influence EMG results include differences in muscles,[2,7] temperature,[1,8-13] and age.[9,12,14] The MUAP duration, amplitude, and number of phases increase with age, with lowest values in infants and children; values reach a plateau in people between 15 and 65 years of age. After people reach 65 years of age, these variables increase further[2,12] as a result of age-related denervation and reinnervation of motor units and selective loss of small motor units.[8,15]

Electromyographic analysis and normative studies have been performed in the subclavian muscle of Dutch Warmblood horses that were 4 to 10 years old[16] and in the subclavian, triceps, and lateral vastus muscles of Dutch Warmblood horses that were 6 to 10 years old.[17] Similar to the situation in humans, differences were found between various muscles in horses,[17] and age-dependent influences on EMG results cannot be excluded in horses. The objective of the study reported here was to examine the potential influence of age on EMG variables. For this purpose, young, adult, and elderly horses were examined.

Materials and Methods

Horses—Three groups of horses were used in the study. One group consisted of 7 healthy young Dutch Warmblood horses. These horses were 13 to 18 months old (mean ± SD, 16.3 ± 2.2 months), weighed between 403 and 557 kg (mean, 483 ± 56.0 kg), and were a height of 1.55 to 1.65 m (mean, 1.59 ± 0.04 m) at the top of the shoulders. The second group consisted of 7 healthy adult Dutch Warmblood horses. These horses were 6 to 10 years old (mean, 7.4 ± 1.81 years), weighed between 563 and 690 kg (mean, 630 ± 45.2 kg), and were a height of 1.62 to 1.69 m (mean, 1.66 ± 0.03 m) at the top of the shoulders. This group comprised nongrowing adult horses. Results for this group have been reported elsewhere.[16] The third group consisted of 7 healthy elderly Dutch Warmblood horses. These horses were 18 to 21 years old (mean, 19.4 ± 1.0 years), weighed between 586 and 692 kg

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Received April 15, 2002.
Accepted August 1, 2002.

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The authors thank C. K. Tims and A. Klarenbeek for technical assistance and J. van den Broek for statistical assistance.

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(mean, 628 ± 37.0 kg), and were a height of 1.59 to 1.70 m (mean, 1.64 ± 0.05 m) at the top of the shoulders. This group comprised the oldest horses that are still commonly examined in a clinical setting despite their age.

EMG procedure—Details of the EMG examination in horses have been published elsewhere.[16,17] The 7 young horses were inexperienced with regard to the EMG examination. Thus, they were administered detomidine[a] (0.2 to 0.3 mg of detomidine, IV) to enable the procedures to be conducted while the horses were restrained in stocks. Adult and elderly horses were not sedated prior to EMG examination. Rectal and intramuscular temperatures were recorded before and after the EMG examination in accordance with the procedure described elsewhere.[16,18,19] Temperature measurements before the EMG recordings were obtained from the contralateral corresponding muscle to prevent interference with recording of the MUAPs.

EMG analysis—Spontaneous activity was analyzed when it was detected outside the endplate region and from stored periods in which the initial 20 MUAPs were recorded. The MUAP analysis was performed off-line in a semiautomatic manner by use of a variable trigger line that selected identical MUAPs above a chosen threshold amplitude when numerous MUAPs were detected in the stored signal. When few MUAPs were captured in the stored signal, they were analyzed manually. For a MUAP to be included in the analysis, time for the increase of the MUAP (ie, risetime) had to be ≤ 0.80 milliseconds and had to be detected at least 4 times. For each MUAP, reproducibility was checked by superimposing at least 4 waveforms. The MUAPs identified semiautomatically were verified manually, and measurements were corrected as necessary. The initial 20 to 30 MUAPs recorded for each muscle were used for statistical analysis.

Insertional activity—Duration of insertional activity was measured from the beginning of insertion of the needle to the end of the activity. Pathologic spontaneous activity generated by needle placement was not included in the duration of insertional activity.

Spontaneous activity—Definitions were formulated in accordance with those reported in another study conducted by our laboratory group.[19] Fibrillation potentials were defined as regularly firing spontaneous potentials of short duration (approx 5 milliseconds) and small amplitude (approx 50 µV) that had an initial positive phase followed by a negative phase. Positive sharp waves were defined as regularly firing potentials with an initial short-duration, sharp, positive deflection followed by a negative wave of longer duration (total duration, approx 5 milliseconds) and variable amplitude (approx 80 µV). Doublets, triplets, and multiplets were defined as 2, 3, or > 3 MUAPs, respectively, firing repetitively at short intervals (2 to 20 milliseconds). Neuromyotonic discharges were defined as potentials firing at high frequencies (≥ 150 Hz). Complex repetitive discharges were defined as bursts of complex potentials firing with a fixed amplitude and frequency (20 to 150 Hz).

MUAP variables—Several variables were determined for each MUAP. Amplitude was measured from the maximum negative value to the maximum positive value. Duration was measured from the initial deflection from the baseline to the final return to baseline. A phase was defined as the part of the signal between each baseline crossing. Number of phases was counted as the number of baseline crossings plus 1. A polyphasic MUAP was defined as a MUAP with > 4 phases. A turn was defined as a change in direction independent of crossing of the baseline. A complex MUAP was defined as a MUAP with > 5 turns. Risetime was defined as the duration of the fastest positive (or negative) deflection and measured automatically. A satellite potential was defined as a separate spike related within a fixed time interval to the main potential.

Statistical analysis—Distribution of data was analyzed by use of histograms and the Kolmogorov-Smirnov test for normality. Because all MUAP variables were positively skewed, data on MUAP variables were logarithmically transformed (**natural logarithm [ln]**) to derive a normal distribution for statistical analysis. **Geometric mean values (gmean)** that were derived from back transformation of ln-transformed data were used to facilitate interpretation of the data. Independent *t*-tests were performed to calculate group differences for MUAP variables, rectal and intramuscular temperatures, body weight, and height. A 1-way ANOVA with Bonferroni post- hoc testing was performed to determine differences among muscles within a horse. Correlations between MUAP variables, between MUAP variables and temperatures, and between body weight and height and MUAP variables were assessed by partial Pearson correlation coefficients. In addition, **95% confidence intervals (95% CI)** were calculated for nontransformed data. Significance was defined as values of $P < 0.05$ (2-tailed test).

Results

Horses—Mean body weight and height of young horses were significantly ($P < 0.001$ and $P = 0.01$, respectively) less than values for adult horses. Mean body weight of young horses was significantly ($P < 0.001$) less than body weight of elderly horses; however, mean height of young horses was less than for elderly horses, but this value did not differ significantly ($P = 0.056$). Body weight and height did not differ significantly between adult and elderly horses.

Insertional activity—Only minor nonsignificant differences were found for duration of insertional activity among muscles within each group of horses. Mean ± SD duration of insertional activity in young horses for the subclavian, triceps, and lateral vastus muscles (390 ± 76, 373 ± 97, and 338 ± 118 milliseconds, respectively) were significantly ($P < 0.001$) less than those in the subclavian, triceps, and lateral vastus muscles of elderly horses (465 ± 107, 459 ± 100, and 495 ± 95 milliseconds, respectively). Duration of insertional activity of adult horses did not differ significantly from that of young or elderly horses.

Spontaneous activity—Fibrillation potentials were recorded in the lateral vastus muscle of 1 young horse. No other forms of spontaneous activity were recorded in young horses. Positive sharp waves and neuromyotonic discharges were recorded in 1 adult horse. No other forms of spontaneous activity were recorded in adult horses.

Pathologic spontaneous activity was recorded in all muscles in all elderly horses. Fibrillation potentials were found in all muscles of all 7 elderly horses (mean duration, 3.9 ± 2.3 milliseconds [95% CI, 3.6 to 4.1 milliseconds]; mean amplitude, 53 ± 64 µV [95% CI, 44 to 61 µV]). Positive sharp waves were recorded in the triceps and lateral vastus muscles of all 7 elderly horses (mean duration, 4.5 ± 1.9 milliseconds [95% CI, 3.9 to 5.2 milliseconds], mean amplitude, 54 ± 48 µV [95% CI, 39 to 70] µV). Neuromyotonic discharges were recorded in all muscles of 5 elderly horses (mean firing frequency, 191 ± 48 Hz). Doublets or triplets were recorded in all muscles of 5 elderly horses. Complex repetitive discharges were recorded in the subclavian and triceps muscles of 2 elderly horses (mean firing frequency, 120 ± 0 Hz).

Quantitative analysis of MUAPs—The ln-transformation data for MUAP variables resulted in normal distributions, as determined by use of Kolmogorov-Smirnov testing. Pooled means and 95% CI of gmean values for MUAP variables were calculated **(Table 1)**. Pooled ln-transformed data for MUAP variables of each of the 3 groups of horses were graphically displayed as box plots **(Fig 1)**.

Analysis of histograms of MUAP duration in the triceps and lateral vastus muscles of adult and elderly horses revealed a bimodal distribution. Independent *t*-tests revealed that the gmean MUAP duration, gmean MUAP amplitude, number of phases, and number of turns in the subclavian muscle were significantly lower in young horses, compared with values for adult or elderly horses. The gmean MUAP duration, number of phases, and number of turns in the subclavian muscle were significantly ($P < 0.001$) lower in adult horses, compared with values for elderly horses. The gmean MUAP duration and gmean MUAP amplitude in the triceps muscle were significantly ($P < 0.001$) lower in young horses, compared with values for adult or elderly horses. Number of phases and number of turns in the triceps muscle were significantly ($P = 0.03$ and $P = 0.04$, respectively) lower for adult horses, compared with values for elderly horses. The gmean MUAP duration, gmean MUAP amplitude, number of phases, and number of turns in the lateral vastus muscle were significantly ($P < 0.001$) lower in young horses, compared with values for adult or elderly horses. The gmean MUAP duration in the lateral vastus muscle was significantly lower for adult horses, compared with values for elderly horses.

Overall percentages of polyphasic MUAPs in the subclavian, triceps, and lateral vastus muscles were calculated for young (2.1, 1.6, and 1.0%, respectively), adult (6.2, 3.9, and 6.1%, respectively), and elderly (11.3, 4.3, and 5.7%, respectively) horses. Overall percentages of complex MUAPs in the subclavian, triceps and lateral vastus muscles were calculated for young (5.2, 2.1, and 2.1%, respectively), adult (10.1, 5.3, and 9.6%, respectively), and elderly (17.8, 11, and 12.4%, respectively) horses. Percentage of polyphasic MUAPs in the subclavian muscle was significantly ($P < 0.001$) lower in young horses, compared with the value for adult horses, and the percentages of complex MUAPs were significantly lower in the subclavian muscle ($P < 0.001$) and lateral vastus muscle ($P = 0.02$) in young horses, compared with values for adult horses. Percentages of polyphasic MUAPs in the triceps and lateral vastus muscles and percentages of complex MUAPs in all muscles were significantly lower in young horses than in adult or elderly horses; significant differences for these variables were not found between adult and elderly horses.

Satellite potentials were found in the subclavian, triceps, and lateral vastus muscles of young horses in 7.5, 2.1, and 4.2%, respectively, of the pooled MUAPs. Corresponding values for adult horses, which have been reported elesewhere,[16] were 10.1, 5.3, and 9.6%, respectively, whereas corresponding values for elderly horses were 5.3, 0.5, and 2.1%, respectively. Percentages of satellite potentials did not differ significantly among groups of horses.

In young horses, gmean MUAP duration was significantly ($P = 0.01$) longer for the subclavian muscle than for the triceps or lateral vastus muscles, and gmean MUAP duration for the triceps muscle was significantly ($P < 0.001$) longer than for the lateral vastus muscle. The gmean MUAP duration did not differ significantly among muscles within adult or elderly horses. We did not detect significant differences for gmean MUAP amplitude among muscles of young horses; however, gmean MUAP amplitude was significantly ($P < 0.001$)

Table 1—Geometric mean (gmean) ± SD values of logarithmically transformed data for variables of motor unit action potentials (MUAPs) in various muscles of young, adult, and elderly Dutch Warmblood horses

		Young		Adult*		Elderly	
Variable	**Muscle**	**gmean ± SD**	**95% CI**	**gmean ± SD**	**95% CI**	**gmean ± SD**	**95% CI**
Duration (ms)	Subclavian	4.8 ± 1.5†,‡	4.6–5.1	5.9 ± 1.7	5.6–6.3	7.2 ± 1.6†	6.7–7.7
	Triceps	4.3 ± 1.5†,‡	4.1–4.6	6.4 ± 2.0	5.9–7.0	7.1 ± 2.1	6.4–7.9
	Vastus lateralis	3.8 ± 1.5†,‡	3.6–4.0	6.2 ± 2.1	5.6–6.8	7.4 ± 1.9†	6.6–8.3
Amplitude (µV)	Subclavian	154 ± 1†,‡	142–167	220 ± 2	203–239	245 ± 2	223–269
	Triceps	161 ± 2†,‡	143–180	427 ± 3	367–497	404 ± 3	351–465
	Vastus lateralis	164 ± 2†,‡	146–185	356 ± 3	313–06	400 ± 3	342–468
No. of phases	Subclavian	2.3 ± 1.4†,‡	2.2–2.4	2.5 ± 1.5	2.4–2.7	2.9 ± 1.5†	2.7–3.0
	Triceps	2.4 ± 1.3†	2.3–2.5	2.4 ± 1.4	2.3–2.5	2.6 ± 1.4†	2.5–2.7
	Vastus lateralis	2.3 ± 1.4†,‡	2.2–2.4	2.6 ± 1.0	2.5–2.7	2.6 ± 1.4	2.5–2.7
No. of turns	Subclavian	2.6 ± 1.5†,‡	2.4–2.7	2.9 ± 1.6	2.8–3.1	3.4 ± 1.7†	3.2–3.7
	Triceps	2.6 ± 1.4†	2.4–2.7	2.7 ± 1.5	2.6–2.8	2.9 ± 1.6†	2.8–3.1
	Vastus lateralis	2.5 ± 1.4†,‡	2.4–2.6	3.0 ± 1.2	2.9–3.2	3.1 ± 1.6	2.9–3.3

Values reported represent inverse of logarithmically transformed (natural logarithm) data. *The gmean values of adult horses have been published elsewhere.[16,17] †Within a row, gmean value differs significantly ($P < 0.05$) from gmean value for adult horses. ‡Within a row, gmean value differs significantly ($P < 0.05$) from gmean value for elderly horses.

95% CI = 95% Confidence interval.

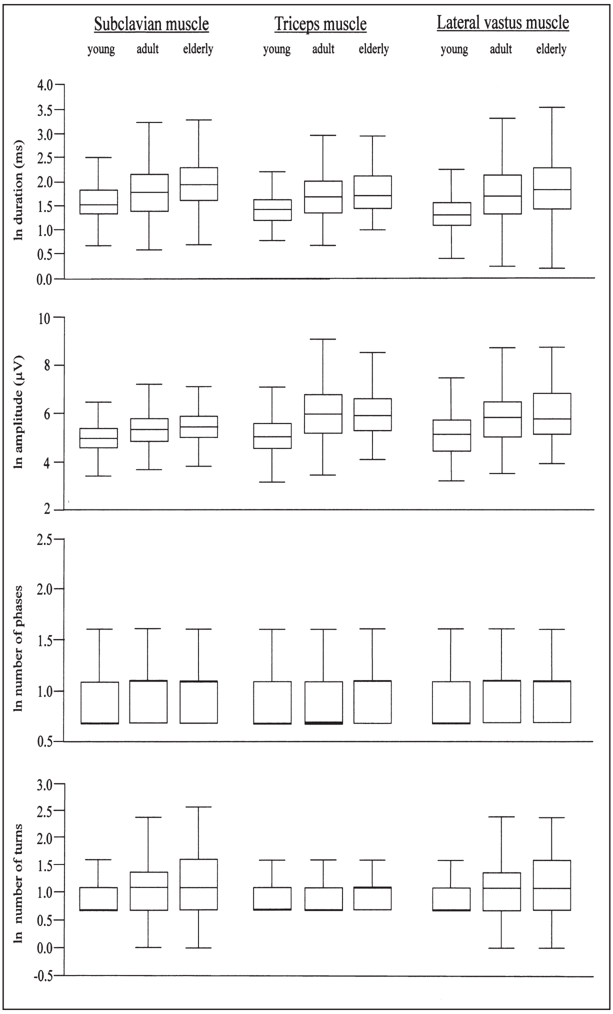

Figure 1—Box plots of logarithmically transformed (natural logarithm [ln]) data for duration, amplitude, number of phases, and number of turns of motor unit action potentials (MUAPs) in the subclavian, triceps, and lateral vastus muscles of young, adult, and elderly horses. The box represents the middle 50% of the values (first to third quartiles), whereas the whiskers represent lowest and highest values. The horizontal line inside each box represents the median value.

lower for the subclavian muscle and significantly ($P = 0.004$) higher for the triceps muscle in adult horses.[16,17] In elderly horses, gmean MUAP amplitude for the subclavian muscle was significantly ($P < 0.001$) lower than that for the triceps and lateral vastus muscles.

Number of phases and number of turns did not differ significantly among muscles within young horses. In adult horses, gmean number of turns was significantly lower in the triceps muscle, compared with the value for the lateral vastus muscle.[17] In elderly horses, the number of phases was significantly higher in the subclavian muscle, compared with values for the triceps ($P < 0.001$) and lateral vastus ($P = 0.02$) muscles. Additionally, number of turns was significantly ($P < 0.001$) higher in the subclavian muscle than in the triceps muscle. The 95% CIs of the 3 groups of horses were calculated **(Table 2)**.

Table 2—The 95% CI values of nontransformed data for variables of MUAPS in various muscles of young, adult, and elderly Dutch Warmblood horses

Variable	Muscle	Young	Adult	Elderly
Duration(ms)	Subclavian	4.9–5.5	6.4–7.4	7.5–8.9
	Triceps	4.3–5.4	7.6–10.0	8.7–11.5
	Vastus lateralis	3.8–4.3	7.8–10.2	9.1–12.2
Amplitude(µV)	Subclavian	167–197	266–334	279–359
	Triceps	188–270	701–1,058	601–927
	Vastus lateralis	199–259	571–836	625–924
No. of phase	Subclavian	2.3–2.6	2.6–2.9	2.9–3.3
	Triceps	2.4–2.6	2.4–2.6	2.6–2.8
	Vastus lateralis	2.3–2.5	2.6–2.9	2.6–2.9
No. of turns	Subclavian	2.6–3.0	3.1–3.5	3.7–4.4
	Triceps	2.5–2.9	2.8–3.2	3.0–3.5
	Vastus lateralis	2.5–2.8	3.2–3.6	3.2–3.7
Polyphasic MUAPs (%)	Subclavian	0.3–3.4	2.0–6.0	2.5–21.9
	Triceps	–0.2–3.4	–13.0–11.2	0.2–7.4
	Vastus lateralis	–0.6–2.3	10.2–14.0	3.1–8.2
Complex MUAPs (%)	Subclavius	0.1–5.2	3.2–8.5	5.6–30.5
	Triceps	–0.6–4.8	–3.1–11.2	0.2–7.4
	Vastus	–0.6–4.8	3.2–16.4	5.6–19.9

Rectal and intramuscular temperatures—Mean rectal temperature of young horses (38.4 ± 0.3°C) was significantly higher than the mean rectal temperature of elderly horses (37.6 ± 0.3°C). Furthermore, mean rectal temperature of young horses was significantly higher than the mean rectal temperature of adult horses (38.3 ± 0.3°C). Mean intramuscular temperature did not differ significantly between recordings and among muscles within each group of horses (37.4 ± 0.5, 36.9 ± 0.3, and 37.0 ± 0.3°C for young, adult, and elderly horses, respectively). Mean intramuscular temperature in the subclavian muscle was significantly higher in young horses, compared with mean values for adult ($P = 0.01$) and elderly ($P = 0.03$) horses.

Correlations—We did not detect a correlation between temperatures and MUAP variables in young horses. Similarly, correlations were not found between temperatures and MUAP variables or between rectal and intramuscular temperatures, as reported elsewhere.[16,17,19] A positive correlation (r, 0.90; $P = 0.02$) was found between intramuscular temperature and MUAP amplitude in the subclavian muscle of elderly horses. Also, a positive correlation (r, 0.90; $P = 0.02$) was found between rectal and intramuscular temperature in the lateral vastus muscle of elderly horses.

A positive correlation (r, 0.83; $P = 0.04$) was found between body height and MUAP amplitude for the triceps muscle of young horses. We did not detect any correlations between body height and MUAP variables in any muscle of adult horses. A positive correlation (r, 0.86; $P = 0.03$) was found between body height and MUAP duration for the triceps muscle of elderly horses. Also, a positive correlation between body height and number of phases was found for the lateral vastus muscle of elderly horses.

We did not detect correlations between MUAP variables in young horses. However, a positive correlation (r, 0.85; $P = 0.03$) was found between number of phases and number of turns in the subclavian muscle of elderly horses. A positive correlation (r, 0.82; $P = 0.04$) was found between number of phases and number of turns in the lateral vastus muscle of elderly horses. Also, a positive correlation was found between MUAP duration and amplitude in the lateral vastus muscle (*r*, 0.84; *P* = 0.04) and between MUAP duration and number of turns in the triceps muscle (*r*, 0.91; *P* = 0.01) of elderly horses.

Discussion

Age differences existed for insertional activity, pathologic spontaneous activity, and MUAP variables. Young horses had the shortest duration of insertional activity, and spontaneous activity was rare in young horses. Also, values for MUAP variables were lowest for young horses. Differences existed between young and elderly horses as well as between young and adult horses and adult and elderly horses. This finding is comparable with EMG results for young, middle-aged, and elderly people.[6,8,9,10,12,15] Analysis of the 95% CI of nontransformed data revealed the same differences as those for results of independent *t*-tests on ln-transformed data, which indicated that these values are suitable for clinical application.

Duration of MUAP, number of phases, and number of turns increased with increasing age of the horses. In addition, pathologic spontaneous activity was frequently evident in elderly horses. In humans, opinions differ on whether positive waves and fibrillation potentials can be found in people above a certain age. In 1 study,[12] these potentials were recorded in up to 30% of clinically normal subjects that were 40 years old, whereas other investigators[18,20] were unable to confirm a high prevalence of these potentials in healthy elderly men.

Our findings may be explained by the concept that after a certain age in humans, effects of aging lead to denervation and reinnervation or selective loss of small motor units.[8,15] These findings are considered characteristic of neurogenic abnormalities when found in younger humans.[1,5,6,10,12] In the study reported here, differences were detected among the muscles examined, but they differed among age groups, indicating that the differences found in the muscles of adult horses cannot be extrapolated to other age categories.

For young horses, detomidine was chosen as a sedative. Because of its mechanism of action, it was not expected to interfere with functioning of the peripheral nervous system and, therefore, the EMG signals. Because horses sedated with detomidine generally sweat, potential increases in intramuscular temperature can be influenced. However, young horses had a higher temperature before sedation than adult horses. As indicated in another study,[18] intramuscular temperature, rather than rectal temperature, is important when determining influences on MUAP recordings.

The high rectal temperature in young horses can be explained by the fact that this group consisted of inexperienced horses that were housed in a herd. Separation from the other horses and restraint in a stock before measurements were obtained induced great excitement in these horses. We did not detect correlations between temperatures and MUAP variables in young horses. In addition, intramuscular temperatures for the triceps and lateral vastus muscles did not differ among age groups of horses. Therefore, temperature differences did not influence the results for these muscles. The positive correlation for the subclavian muscle between intramuscular temperature and MUAP amplitude and intramuscular temperature and number of phases in elderly horses may suggest that an increase in temperature would result in an increase in MUAP amplitude. However, intramuscular temperature of this muscle was higher in young horses than in elderly horses. Therefore, higher values of MUAP amplitude and number of phases in elderly horses were not caused by temperature differences. Intramuscular temperatures in adult horses, including the temperature in the subclavian muscle, did not differ from those for elderly horses.

The positive correlation between number of phases and number of turns and between MUAP duration and MUAP amplitude for the lateral vastus muscle of elderly horses is similar to results documented in adult horses.[16] The correlation between MUAP duration and amplitude can be explained by the relation of both variables to the size of the recruited motor unit.[2,8] The correlation between number of phases and number of turns and between MUAP duration and number of turns can be explained by the relation of these variables to temporal dispersion of MUAP for single muscle fibers.[10,12]

The positive correlation between height and MUAP variables in young horses can be explained by dependence of MUAP duration and amplitude on factors such as muscle fiber diameter and area over which the endplates are dispersed.[10,12] These are factors that can be expected to change during growth.[6] In elderly horses, a positive correlation was detected between height and number of phases and between height and number of turns. This is an interesting finding because these MUAP variables relate to temporal dispersion of the conduction velocity of single muscle fibers, which can increase in neurogenic disorders and aging horses and for which long nerves are more vulnerable than short nerves.[21,22]

Differences were found among muscles for MUAP duration in young horses, which was not found in adult or elderly horses. The MUAP duration depends on the amount of electrical activity generated by the total active muscle fibers recorded independent of the distance to the tip of the electrode. In contrast, differences for MUAP amplitude were not found among muscles in young horses, whereas differences for this variable were found among muscles within adult and elderly horses. Because MUAP amplitude is highly correlated with the number and diameter of muscle fibers in close proximity to the electrode tip, a possible explanation for these differences could be that differences in muscle fiber diameter among muscles are not evident in young horses, but differences in recorded number of muscle fibers are. Studies on motor unit territories in horses could clarify this, but to our knowledge, such studies have not been performed. Differences found among muscles in adult horses represent differences in fiber type distribution. Type-I fibers have the smallest diameter, and the subclavian muscle has the most type-I fibers, which explains the lowest amplitude.[17] Aging in humans results in replacement of type-II muscle fibers with type-I muscle fibers.[22] If this also occurs in horses, it could explain the loss of difference in the triceps muscle and lateral vastus muscle, which originally have a high number of type-II fibers, by a more uniform distribution of muscle fiber diameters.

In the triceps and lateral vastus muscles of elderly horses, a bimodal distribution of MUAP duration was seen, similar to the results of these muscles reported for adult horses.[17] This is most likely caused by recruitment of small motor units or large motor units that are not equal for the examined muscles. This phenomenon was not seen in young horses in which it was much easier to induce MUAP activity in the triceps and lateral vastus muscles because of the higher muscle tone caused by their nervousness and, thus, more excitable nature, compared with adult horses, which suggests that a more gradual recruitment of motor units[11] could be induced in young horses.

It can be concluded that when normative data for MUAP analysis are applied for clinical use, age-related influences must be taken into consideration and are of importance for correct interpretation of the recordings. Ignoring age differences could result in the risk of misinterpretation of normal MUAPs in young horses as myopathic MUAPs or considering large, broad, polyphasic MUAPs as indicative of neuropathy in healthy elderly horses. It has been suggested that detection of fibrillation potentials and positive sharp waves are indicative of lower motor neuron disease in horses, whereas at the same time, it has been concluded that the risk of lower motor neuron disease peaks at 16 years of age in horses. Therefore, it is essential to perform MUAP analysis during EMG examination, because if fibrillation potentials and positive sharp waves are considered to be evidence of disease in elderly horses,[23-26] the risk of false-positive results attributable to this type of activity may also be found in healthy elderly horses.

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